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of the
American Welding Society

October, 1929

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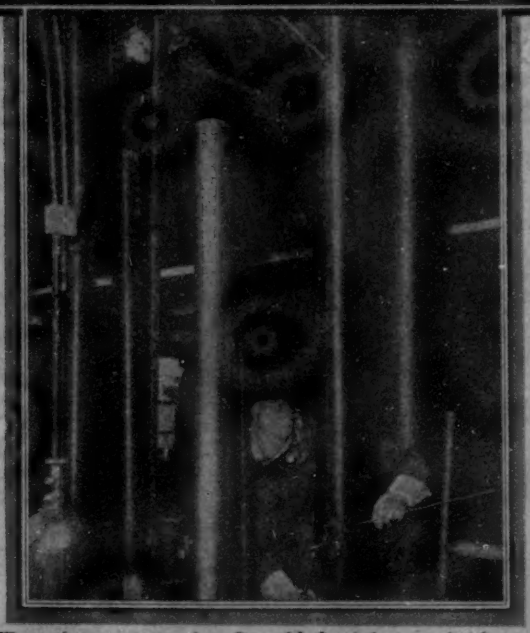
. . As to Modern Piping . .



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JOURNAL

of the

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AMERICAN WELDING SOCIETY
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JOURNAL

Volume 8 OCTOBER, 1929 Number 10

1929 Fall Meeting

The 1929 Fall Meeting of the American Welding Society was held in Cleveland, Sept. 9 to 13. There was a registered attendance of 400 members and their guests, which indicates the continued growth of the Society and interest in its affairs.

There were six technical sessions at which a total of 16 technical papers were presented. Of these a majority dealt with the results of research work and four papers were reports of workers on the Fundamental Research Committee of the American Bureau of Welding.

Most of the papers were printed in the September issue of the JOURNAL and distributed in advance of the meeting. The few remaining papers will be printed in subsequent issues. These papers together with the discussion probably represent one of the most complete reviews of welding knowledge gained during the past few years.

In addition to the technical sessions a number of committee meetings were held, including the Board of Directors of the American Welding Society; the American Bureau of Welding and its committees on Structural Steel and Fundamental Research. There were also meetings of the National Membership Committee of the American Welding Society; the Program Committee of the International Acetylene Association and the Arc Welding Committee of the A.I.E.E.

A complete and varied program of entertainment was provided for the ladies throughout the entire session.

Two alternative inspection trips were arranged; one of them included a bus trip to the Burdette Oxygen Company, the Joseph T. Ryerson Company, where there was an exhibition of automatic cutting, and the Lincoln Electric Company, where the visitors were served a buffet luncheon. The other included an airplane trip to Akron, which was sponsored by the Goodyear Rubber Company.

The Fall Meeting Dinner and Dance of the American Welding Society was the outstanding social feature of the occasion. About 150 people were present.

Visiting engineers were impressed with the remarkable advance that has been made in welding during the past few years and the scientific knowledge available in regard to the various problems and phenomena involved.

Member for Member Campaign

At a recent meeting of the National Membership Committee, it was unanimously decided to launch a "Member for Member Campaign." The success of such a campaign depends very largely on the enthusiasm and cooperation of the members of the American Welding Society.

The American Welding Society is regarded as the foremost organization in the weld for advancing the knowledge and art of welding and extending its applications. Everyone identified with the welding industry should be affiliated and become a part of it.

The success of a Society such as ours depends very largely on the number and quality of its members. It is hoped that this "Member for Member Campaign" will result in practically doubling the present membership.

The Society needs additional funds in order that it may broaden out its activities, increase the size of the JOURNAL, bring forth additional codes and specifications and do more research work. Such activities will be of benefit to the welding industry and to every member of the Society. This increased revenue can be obtained through additional members.

The Membership Committee respectfully requests the cooperation of

FALL MEETING DINNER OF AMERICAN WELDING SOCIETY, HELD IN CLEVELAND, SEPTEMBER, 1929

every member in this campaign by securing a new member. Every member knows someone in the industry who should be affiliated with the Society.

The Membership Committee feels that the accomplishments of the Society and its work are such that it should be no difficult task for each member to secure one new member if the opportunities and advantages of becoming affiliated with the Society are pointed out to the prospects.

Welding Session at Petroleum Exhibition

Arrangements have been completed for a welding session at the Sixth International Petroleum Exhibition, to be held in Tulsa, Oct. 5 to 12. Several important papers will be presented at the time and plans are under way for organizing a Tulsa Section.

International Acetylene Association Convention

Announcement has been made that the Annual Convention of the International Acetylene Association will be held at the Congress Hotel, Chicago, November 13, 14 and 15. The Program Committee has made definite arrangements for a number of papers of unusual interest. Members of the American Welding Society are invited to attend the meetings.

Research and Confidence

(Reprinted from Sept. 19, 1929, issue Engineering News Record)

Structural engineers and welding specialists alike have ample cause to regard the meeting of the American Welding Society in Cleveland last week with considerable optimism. For out of it came substantial promise that means are at hand or almost at hand whereby a weld may be definitely evaluated without destroying it. And also out of the meeting came F. T. Llewellyn's pronouncement in his presidential address that the one aim of the present administration is to create confidence in welding. It is no secret that the structural engineer has lacked confidence in welding in spite of many successfully welded structures that raise themselves to shake his belief. Furthermore, it is true that the bulk of his uneasiness concerning the safety of welding has arisen from his lack of non-destructive testing means. Visual inspection is too intangible to be entirely adequate. Much hope, therefore, rests in the announcement of successful research on three tangible testing and inspection methods of a non-destructive nature: The physician's stethoscope was found an effective means of detecting flaws in welds; the X-ray disclosed the location of flaws on its shadowgraphic negatives; and the electric current, found to balk at a flaw, was made to reveal the balk on the chart of recording apparatus.

Time and again experience has shown that real progress in any technical field is dependent upon these two factors—research and confidence. They have provided a rich legacy for the concrete art; one has followed the other in the field of alloy steels for bridges; and aviation is now reaping its reward in confidence for many years of diligent research. There is no question that welding research has hardly begun in the field of structural steel. In view of the American Welding Society's expressed desire to create confidence, this research is certain to be carried on with increasing zeal. If history repeats itself, this reseach will provide the structural engineer with the confidence in welding that he has longed for. Therefore his cause for optimism at the present outlook.

SECTION ACTIVITIES

Boston

The Boston Section arranged a bus party to Groton, Conn., on Oct. 5 to attend the launching of an all-welded barge 110 ft. overall length by 34 ft. beam by 11 ft. 6 in. molded depth, built by the Electric Boat Company. After the launching everyone present was allowed to go aboard the barge to examine its construction details.

The Boston Section of the American Welding Society sponsored and managed an elaborate meeting on

Structural Steel Welding and Cutting under the auspices of the Engineering Societies of Boston on Oct. 10. The meeting was held at the Massachusetts Institute of Technology and included representatives from the Member Societies as follows:

Boston Society of Civil Engineers.
New England Water Works Association.
Plant Engineers' Club.
Boston Section, American Institute of Electrical Engineers.
Boston Section, American Society of Mechanical Engineers.
Northeastern Section, American Society of Civil Engineers.
Boston Section, American Institute of Mining and Metallurgical Engineers.
Massachusetts Chapter, American Society of Heating and Ventilating Engineers.
Boston Chapter, American Association of Engineers.
Boston Post, The Society of American Military Engineers.
Boston Section, American Welding Society.
New England Section, Illuminating Engineering Society.
The Massachusetts State Engineers' Association, Inc.

The program included opening remarks and words of welcome by Mr. C. W. Babcock, chairman of the Boston Section, American Welding Society; Dr. S. W. Stratton, president of M. I. T., and Prof. E. F. Miller of M. I. T., and also by Mr. Alfred Kellogg, chairman of the Engineering Societies of Boston.

Four papers were presented as follows: Electric Arc Welding, by Prof. Frank P. McKibben of Black Gap, Pa.; Electric Arc Welding, by Mr. A. M. Candy of the Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa.; Gas Cutting of Steel, by Mr. J. J. Crowe of the Air Reduction Sales Company, New York City.; Fabrication, by Mr. P. J. Horgan of the River Works Plant of the General Electric Company, West Lynn, Mass.

These papers were followed by demonstrations of gas steel cutting, arc welding into predesigned specimens, and testing of the welds to destruction. Prizes were offered to those estimating the nearest number of pounds required to break the weld or structure tested. An elaborate souvenir program of 24 pages and covers was distributed at the meeting.

Chicago

At the opening meeting of the Chicago Section held on Thursday, Oct. 3, at the Greer College, Mr. W. M. Dunlap, Metallurgical Research Bureau of the Aluminum Company of America, presented a paper, entitled "Welding in the Aluminum Industry." Mr. Dunlap's paper covered a program of research of the Aluminum Company of America, which has been in progress for considerable time. Many interesting points and procedure for the successful welding of aluminum were included.

As an additional feature, Mr. R. P. Monroe of the Burlington Railroad gave a practical demonstration of bronze welding. The material on which he worked was so arranged that he applied bronze in vertical, overhead and horizontal positions.

In arranging the programs of the Chicago Section, the committee has decided to include a practical demonstration of some form of welding, having an expert in some line, handle the work at each meeting. This addition to the regular monthly meetings has been included followed the requests of several members of the section, for something of this nature. The splendid turnout at the opening meeting indicated that there will be wide interests and large attendance at all of the meetings of the section this year.

Los Angeles

The first meeting this fall of the Los Angeles Section was held on Oct. 16. Mr. David J. Witmer, architect, who is on the Technical Staff of the Building Code Committee for a Uniform Building Code for California, told about the work of this committee and about the parts of the code regulating welding. The meeting was preceded by a dinner at 6.30 in the L. A. Cremery Banquet Hall.

New York

A most interesting meeting of the New York Section was held on Oct. 15. A two reel motion picture was shown on "The Welding of Structural Steel" with introductory remarks by H. H. Moss, engineer, Development Dept., Linde Air Products Company. A paper on "Developments in Stethoscopic Testing of Welds" was presented by Messrs. A. R. Lytle and A. B. Kinzel of the Union Carbide Research Laboratories. Messrs. Lytle and Kinzel uncovered for the first time in New York, the remarkable developments in non-destructive testing of welds.

Philadelphia

The September meeting of the Philadelphia Section was held on the 16th. Mr. R. H. Luckenbach spoke on the subject of "Safety in Welding." Mr. H. J. Larsen, the other speaker at that meeting, gave a very interesting talk on "Eye and Head Protection in the Industry."

At the October meeting which will be held on the 21st, Mr. E. R. Fish, manager of engineering, Combustion Engineering Corp., will present a paper on "Boiler Welding." Mr. C. W. Obert, consulting engineer, Union Carbide & Carbon Research Laboratories, will talk on "The Present Status of Welding in the A. S. M. E. Boiler Code." Both of these subjects contain much of interest and value.

The November meeting will be held on Monday evening, Nov. 18, at the Engineers' Club. Mr. John N. Zink, president, The Heat & Power Corporation, Baltimore, Md., will give a talk on "Pipe Welding as Applied to Industrial and Building Operations."

Employment Service Bulletin

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Electrical Welding of Pipe and Tubing for Boilers, Heating, Refrigeration and Other Uses*

H. A. WOOFTER†

THERE is an old adage to the effect that the civilization of any country or people is directly proportional to the amount of sulphuric acid it consumes. Another is to the effect that the civilization of a country is directly proportional to the kilowatts of electricity generated and consumed therein. We would like to suggest another one, namely, that the civilization and development of any country is directly proportional to the amount of piping or tubing which it uses. Piping of various sizes for water, gas, fire protection, sewers and other purposes makes comfortable living conditions in our large cities possible, as well as in the enormous skyscrapers in those cities. The first pipe used in this country was made from lags with a hole bored through the longitudinal axis, and occasionally these wooden pipes are dug up when excavating under the streets of our older cities. Now, however, pipe plays an enormous and important part in the development of oil fields for handling crude petroleum, casings and tubings for oil wells, pipe for gas lines, in steam boilers for stationary, marine and all other uses; in fact, if all pipe were to be suddenly destroyed, it would be the greatest calamity that could befall the civilized race.

The earliest metal pipe was made from soft charcoal iron and specimens of such pipe welded by some means, evidently by blow torch, have been discovered in ruins of ancient cities. Piping and tubing as used at present consists of a moderate amount of soft charcoal iron pipe for certain uses, and enormous amounts of lap-welded steel pipe, as well as a great deal of seamless steel tubing.

We will omit from this discussion various other classes of pipe, such as lead pipe, copper and brass pipe, etc., since, while they play an important part in our civilization, they are not within the scope of this paper. The best pipe made, of course, is seamless steel tubing, but its cost makes it too expensive to use for many purposes. Lap-welded pipe is much cheaper but is subject to the criticism that it often splits or parts along the seam when strained by freezing or when subjected to high pressures of any kind or to excessive vibration. A happy solution to these two extremes has been brought about by the electric welding of pipe and tubing of medium diameters, which, up to 2 in. or a little over, can be made at the rate of about 100 feet per minute, while larger pipe, say up to 5 and 6 in. diameter, can be made at the rate of from 40 to 50 feet per minute. The method used is the resistance welding process and the machine is usually of the stationary type, where the pipe is formed in a forming machine from flat stock into a split tube and then put through

*Presented at Fall Meeting, A. W. S., Cleveland, September, 1929.
†Chief engineer, Swift Electric Welder Co.

the welder in the same continuous process of forming, coming out complete at the other end with the butt rolled down both inside and out and ready for use.

The matter of the longitudinal welding of pipe is, of course, of interest to only a few, namely, the manufacturers of pipe, but the circumferential welding, which is commonly known as butt welding, meaning the connecting of pipe end to end, is a matter that affects practically every user of pipe all over the country and is, therefore, a matter of wide interest to practically all manufacturers who use pipe in some form or other. This paper will deal mostly with circumferential welding, which is of

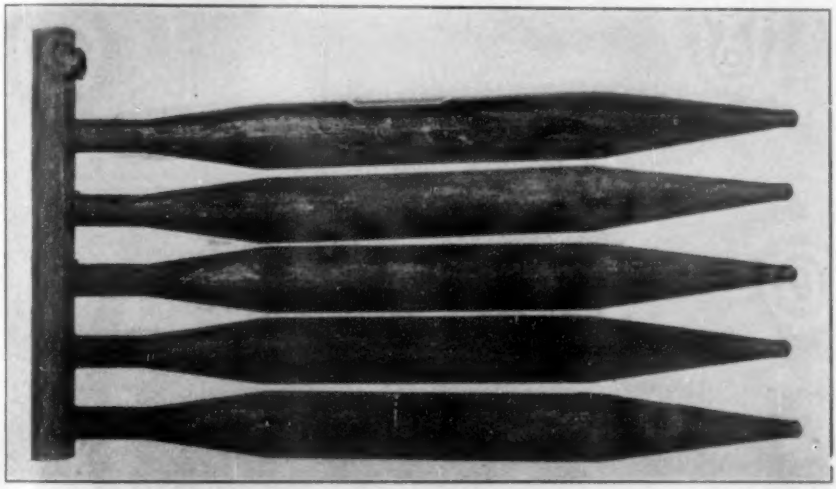


FIG. 1—WELDED PIPE CLUSTER FOR ELECTRIC REFRIGERATION. ONE PIPE OMITTED TO SHOW FLANGE

most general interest. The time honored and antiquated method of connecting pipe is, of course, by means of thread and collar, but the very act of threading a pipe on each end cuts away a large amount of the cross-section of stock leaving it inherently weak at that particular point and extremely subject to rusting, corrosion and various other destructive agents. Now, while threads and collars will always be used in certain places, especially those of temporary installation or which must be removed at some future time, for all permanent uses electric welding is cheaper and better from all standpoints. In the case of pipe lines where the work to be done may be a long way from any source of electric power, the welding is usually done by means of the arc welding process, or by the acetylene process. However, in a large plant, such as locomotive repair shops, locomotive manufacturing plants, heating and ventilating plants, refrigerator plants, etc., the welding is usually done by means of the resistance process, where the work is brought to the welder rather than the welder to the work.

Let us first consider some welding jobs of small pipe. Fig. 1 illustrates an assembly of small drawn tubes welded to a common head, and is used extensively in the making of electric refrigerators. The stock is usually

.035 in. thick and these assembled parts are tested at 400 lb. pressure per sq. in. This will give you some idea of how strong these welds must be in order to be absolutely safe when used in the building of electric refrigerators wherein a leak in the brine circulation will often cause poisoning of the food, with sometimes death to the persons consuming it. These welds are made one at a time in rapid succession and finally the completed piece, which is often several feet long, is tested all at one time at 400 lb. pressure under water strongly charged with soap, so that in the

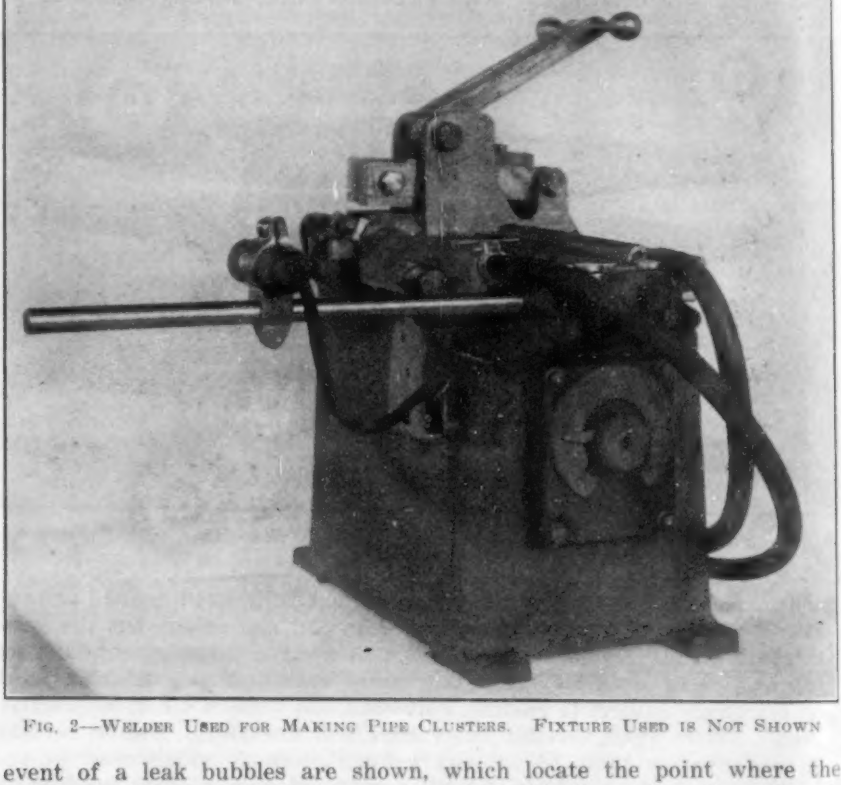


FIG. 2—WELDER USED FOR MAKING PIPE CLUSTERS. FIXTURE USED IS NOT SHOWN

event of a leak bubbles are shown, which locate the point where the leak is. However, few leaks are found in this line of work, and such leaks are stopped by use of an arc or gas welder.

Fig. 2 illustrates the type of welder used for making these refrigerator parts.

Fig. 3 illustrates a rather unusual welding job, wherein small pipes are welded at right angles against the walls of larger pipe to make soot cleaners for steam boilers, also this same method is used in making sprinklers and irrigating pipes for truck gardens. This type of job can be accomplished on any fairly standard type of welder by making special clamps or fixtures to hold the work.

While it is fairly common practice to weld pipe at right angles, as, for

instance, in the manufacture of gas and oil stoves, etc., it is also common practice to miter the pipe and make miter welds at corners for window sash, railings, frames, etc. Another somewhat unusual pipe welding job is in the manufacture of steam ovens for bakeries, wherein there are dead ends on certain pipes. The dead end is usually a punching or stamping or drawing, although sometimes it is a steel casting or drop forging, and is welded on to the end of the pipe to close it. This is best illustrated in Fig. 4, showing a few of the unusual shapes of piping for this particular use. The baking ovens usually use pipe about 1 in. inside diameter with extra strong wall.

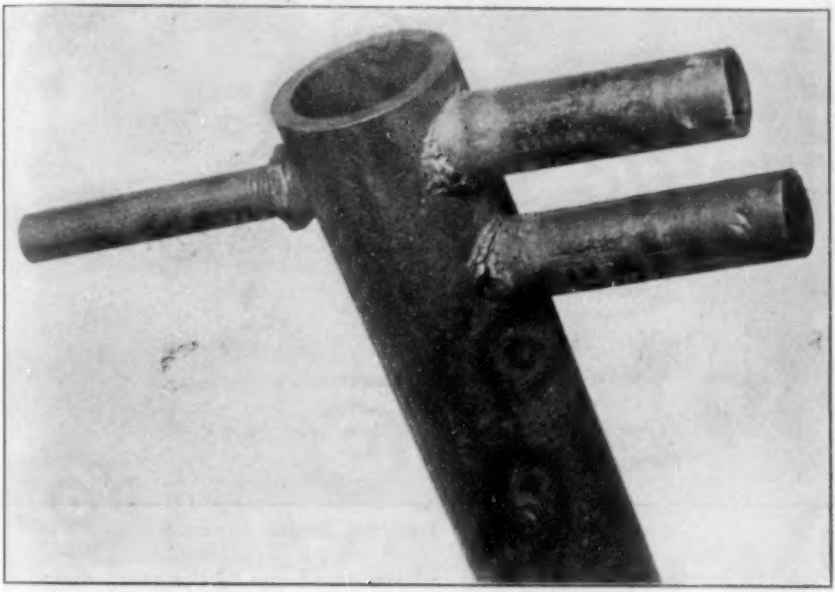


FIG. 3—SMALL PIPES AND NIPPLE WELDED AT RIGHT ANGLES ONTO LARGER PIPE

This same principle is used in mercury boilers, recently developed by Mr. W. L. R. Emmets of the General Electric Company, but in the case of mercury boilers the pipe is larger, usually 2 in., and is usually made from a special alloy sold under various trade names, such as Induro, etc. These special alloys have a large content of nickel, also usually some chromium and often vanadium to give toughness. The alloys usually lend themselves to welding very readily, but are extremely hard to push up, due to the density of the alloy. In fact, a 2 in. alloy tube with a wall about .15 in. thick often requires as much pressure to push up the weld as a 2 in. diameter solid steel shafting. This will give an idea of some of the unusual problems encountered in welding some of the new alloys, not only from an electrical standpoint but from a mechanical standpoint as well. It requires a welder with hydraulic cylinder to push up these welds and this cylinder can either be operated from a hydraulic accumulator or from an Oilgear pump, as desired. When operated from an Oilgear pump with proper control the outfit is termed a Semi-Automatic Welder.

Fig. 5 illustrates a Semi-Automatic Welder for pipe, tubing, etc., such as just described, but this same device can also be used for solid stock, either in round, rectangular or flat cross-section, if so desired, by using properly shaped dies.

One of the most interesting pipe-welding jobs is that in connection with manufacture and repair and upkeep of locomotive boilers. While everyone travels by train, very few persons realize the romance connected

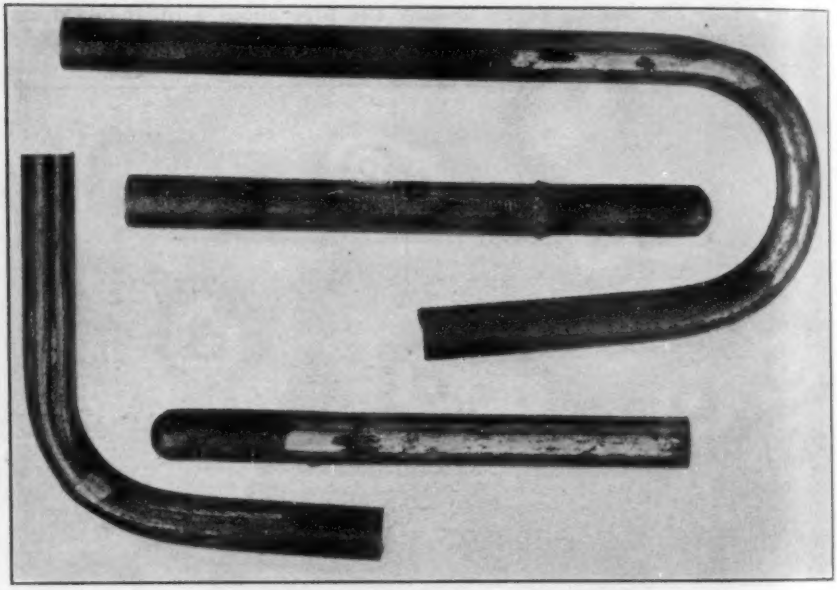


Fig. 4—Dead Ended Pipe for Steam Bakeries

with the locomotive which draws the train and one of the most romantic features is that in connection with the flues and tubing of the boiler itself. In locomotive boilers there is a severe corroding and pitting action around the flues and tubing where they pass through the front and rear boiler heads. The rapidity and severity of this corroding and chemical action is almost entirely due to the nature of feed water used and consequently the destruction of tubes varies widely in different localities. In New England, where the water is soft, a set of good locomotive tubes and flues will operate for five or six years without requiring safe endings. In hard-water districts, however, such as the Lake Shore country or the Middle West or Northwest, where the feed water contains calcium carbonate, sulphide, gypsum, strontium, sulphur, iron and many other impurities, it is often necessary to remove the flues and tubes about every five or six months and cut off the weakened ends and weld a new piece 10 or 12 in. on one end of the tube or flue. This is known as safe-ending. The flues and tubes are then reassembled in the boiler, where they will operate for another period, when it again becomes necessary to safe-end them. In the course of a few years the flues and tubes sometimes have as many as 10 or 12 safe ends welded on at different periods before

they are finally scrapped. There are often 300 or more flues in a locomotive, which are usually 2 in. or 2¼ in. outside diameter. The number of superheater tubes varies, but they are usually from 56 to 64 in number in each boiler and the diameters vary, but the most common size is 5⅜ in. or 5½ in. or 6 in. outside diameter. In each of these superheater tubes there is a cluster of 2 or 4—1-in. inside diameter pipes, made in a continuous coil, which carries the steam through the hot gases of combustion, superheating and drying it. The return bends in these steam

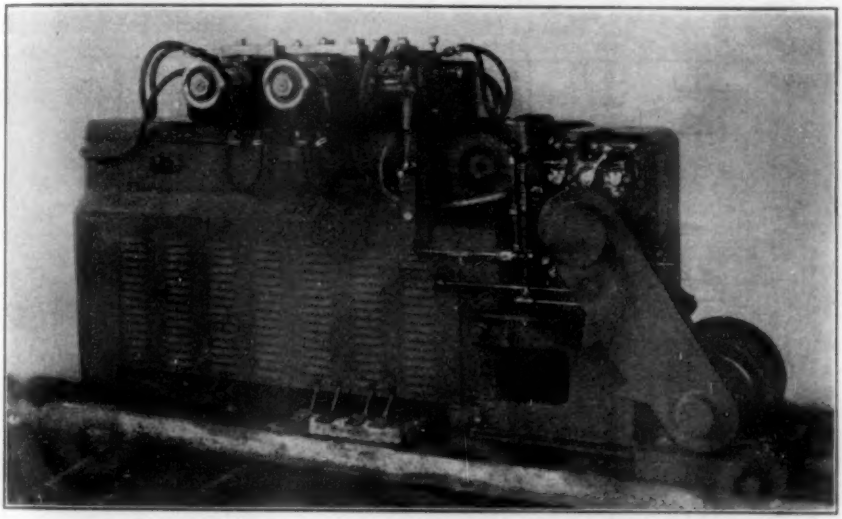


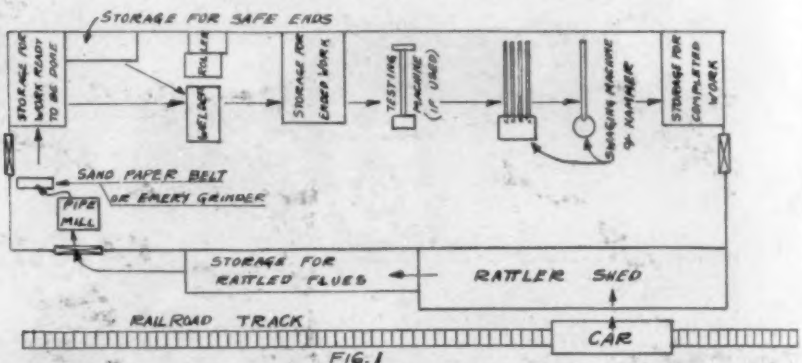
FIG. 5—SEMI-AUTOMATIC WELDER FOR SAFE-ENDING LOCOMOTIVE FLUES AND TUBES FROM 2 IN. TO 6 IN. OUTSIDE DIAMETER. IT IS ALSO USED TO WELD PIPE INTO GREAT LENGTHS FOR WINDING INTO HEATING COILS, OR REFRIGERATOR COILS OR WATER TUBE HEATERS

coils are often welded and this matter will be referred to later. The flues and superheater tubes when first removed from the boiler are always encrusted with a thick deposit, called scale, which is thrown down from the hot feed water. It sometimes attains a thickness of ⅛ in. in extreme cases. To remove this deposit the flues and tubes are loaded into a revolving drum or rattler in which steam, water and certain chemicals are injected to soften and help remove the scale. The drum is revolved for several hours, which usually removes the scale sufficiently that the old stock can be placed in the welder and welded without any additional cleaning. If, however, the rattling process has not sufficiently cleaned the old stock, it is necessary to clean it on a sandpaper belt, which requires but a second or two. By having the work clean, both old and new, the upkeep on the dies is greatly reduced and more uniform results are obtained in the safe-ending.

Fig. 6 represents one layout of a modern flue-welding room. However, practically every railroad has its own idea of the correct layout of a flue-welding room and the shops vary from railroad to railroad. This figure also illustrates both obsolete and modern methods of preparing the work for welding. The influence of the old flame and

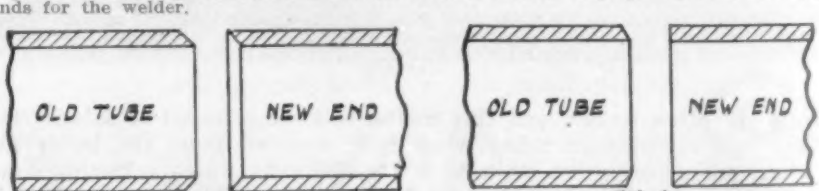
forge process of safe-ending is shown in Fig. 2 in this cut, where the railroad operators found it necessary to scarf the ends of the work, one piece on the inside and one on the outside, so that in the process of welding they would be thrust into one another somewhat like thrusting the finger into a thimble. This was also probably partly due to the fact that in those days there was no flash welding and the work was done by means of butt welding wherein the work was first pressed together and then the current thrown on and allowed to heat entirely by the P

Figure 1 shows a layout of a modern flue welding room.



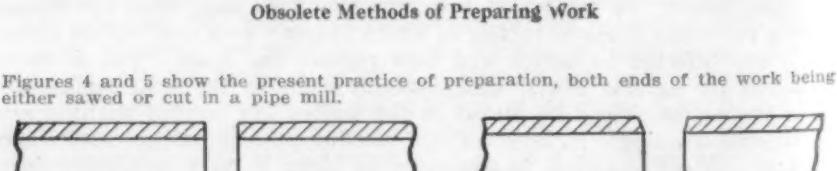
Arrangement of a Flue Welding Shop using an Electric Welder. Two welders may be used by making another line of work down the other half of the same room. Arrows indicate travel of work to completion.

Figures 2 and 3 represent what is now an obsolete method of preparing flues and safe ends for the welder.



Obsolete Methods of Preparing Work

Figures 4 and 5 show the present practice of preparation, both ends of the work being either sawed or cut in a pipe mill.



Latest Methods of Preparing Work

Ends sawed off or cut in pipe mill. Ends cut by disc cutter.

FIG. 6—LAYOUT OF MODERN FLUE WELDING SHOP

R formula. However, this was in 1912 and welding methods have greatly changed since that time. The old butt welding method of resistance welding has almost entirely passed out of the picture and flash welding, contact flash welding and other later methods have superseded it. Later on they found that it was only necessary to scarf one of the pieces and the other end might be left square as shown in Fig. 3. Now, however, with flash welding available and with powerful electric welders it is no longer necessary to scarf or chamfer the work, but it may be cut off in a pipe mill, sawed off in a friction saw or any other approved method, and any irregularities on the ends are immediately burned off

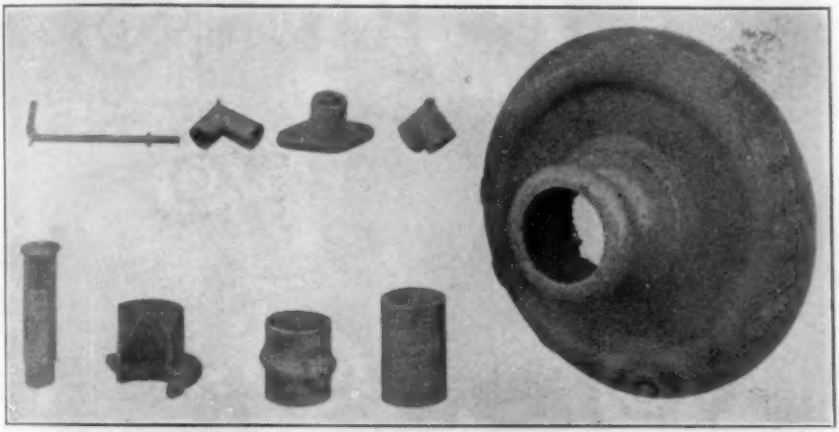


FIG. 7—SAMPLES OF WELDED WORK. THE LARGE WIRE WHEEL HUB SHOWN IN THIS PHOTOGRAPH WAS HANDLED ON THE MACHINE SHOWN IN FIGURES NOS. 8, 9 AND 10

by the flash and a much better and stronger weld is procured than was ever possible by the butt welding process. In fact, the butt welder produced a weld which was seldom over 90 per cent as strong as the original flue or tubing; whereas the present flash welding method produces a weld that is about 110 per cent or more as strong as the parent metal itself, due to the refinement of the grain caused by the enormous pressure at the instant of push-up, which makes the grain of the metal more dense and stronger in the region of the weld than elsewhere.

For the safe-ending of flues from 2 in. to 3½ in. diameter a relatively small welder may be used which may be entirely hand operated or it may have air-operated clamps with hand-operated push-up.

For larger flues and superheater tubes a larger welder is required, which invariably has air-operated clamps with foot-controlled valves and also has some form of mechanical push-up, since it is impossible for a man on a compound toggle device to push up these large flues and tubes.

In the old forge and fire weld days, a production of 30 to 35—2-in. flues per hour with a crew of three men was considered satisfactory work. With a modern resistance welder two men can produce 120—2-in. flues per hour, and, best of all, they will all be good welds; whereas, with the forge and fire welds, a large rejection of leaky flues always occurred, sometimes as much as 10 or 12 per cent of the total number welded.

Oxides from the burning oil or gas were invariably imprisoned in the long scarf welds in greater or less degree, making scabs or spots where there was no weld, so that it was often necessary to cut off the weld and make it over again. Now, however, with resistance welding, since no scarfing is required, enormous pressure can be obtained on the flat ends of the pipe which closes up all pores, and all oxides or burned metal are thrown off with the flash.

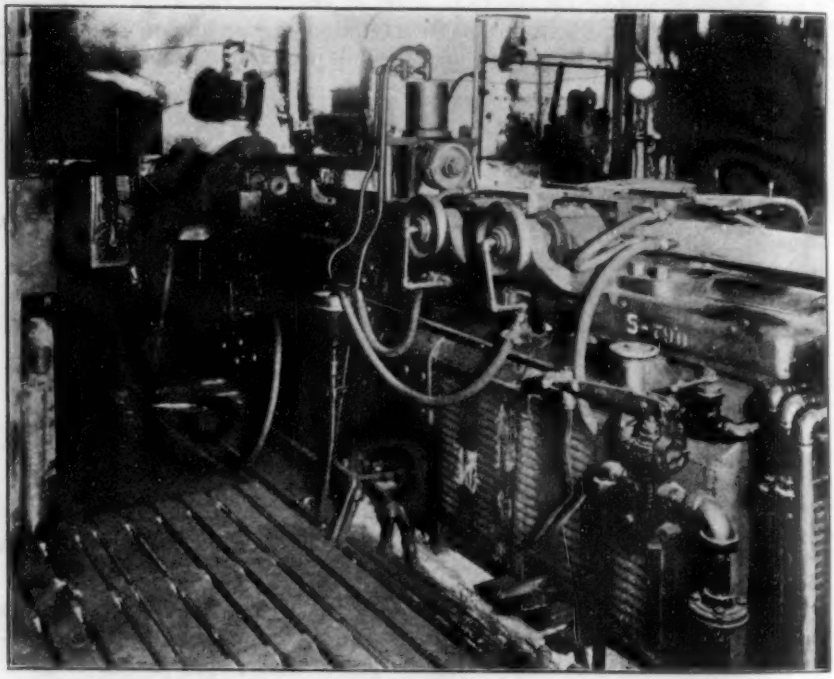


FIG. 8

This powerful push-up, however, tends to thicken the wall of the flues at the point of weld and if left in this condition it would restrict the inner diameter and retard the passage of flue gases or the use of soot scrapers or swabs. To overcome this matter, the instant the weld is completed, some additional heat is given the flue by pressing the push button for an instant and then giving it some additional pressure which presses out the weld in a fold as shown in the middle of Fig. 7. The flue is then instantly released from the clamps and shoved over a mandrel where it is rolled down by means of three revolving rollers on the outside of the flue so that the completed weld is as shown in Fig. 7 at the right of the central figure. The rolling requires only three or four seconds of time for small flues, and relatively longer for superheater tubes. Fig. 8 shows part of the rolling device, where it is placed at the left hand end of the welder. When the clamps are released the hot work is thrust endwise over the central mandrel.

If it is desired to make a thrust-collar stabbing ring on the pipe for

the use of a copper ferrule, this collar may be upset as shown to the left of the central figure in Fig. 7. Either of the three shapes shown in the lower line-up of Fig. 7 can be made at the same instant as the weld and at the same heating; hence, this process lends itself beautifully to a great many other uses in addition to flue welding. For instance, if the pipe is to be prepared with a stabbing ring or thrust collar to take expansion joints or expansion collars, it is very easy to make the upsets or collars right in the welder at the time of welding. These thrust collars are being electrically made on pipe up to 22 in. diameter.

The hub shown in the right hand margin of Fig. 7, while it is not a pipe welding job, it is very similar, in that both the large and small

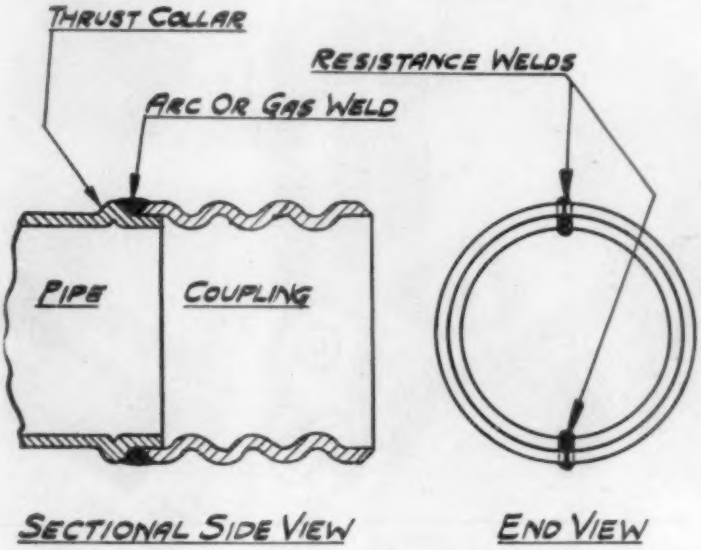


FIG. 9—EXPANSION COUPLING

pieces of the hub are circular and are welded together by the flash process just the same as jointing two pieces of pipe. Also the three central figures in top row of Fig. 7 are pipe jobs, the welds being easily apparent by inspection. The one on the left of the central part is for frames and windshields, or for metal screens, or made in a slightly different form for metal sash for windows. The one on the right is usually used for railings, guards and metal furniture and a number of other purposes, where pipe is miter-welded together.

The article in the lower left hand corner of Fig. 7 is a valve stem, very similar to a pipe welding job, but having a white cast iron head welded on to a chromium steel hollow shank. Jobs similar to these can be accomplished on practically any standard resistance welder, but the production obtained depends largely on the equipment of the welder; that is to say, whether or not it has hand or air operated clamps or whether it is hand or automatically operated. These special features are a matter of choice on the part of the manufacturer. He can obtain a larger pro-

duction by buying a more expensive welder or a smaller production by investing in a lower priced welder. However, cost records show that the high production welders are the cheapest in the long run since they often save an extra helper and give much greater production for a given number of feet of floor space.

The thrust collars or stabbing rings shown in Fig. 7 have a still further use that has recently come into general practice. Before the advent of welded pipe lines, it was customary to thread the pipe and connect the various sections together by means of pipe couplings. Now, however,

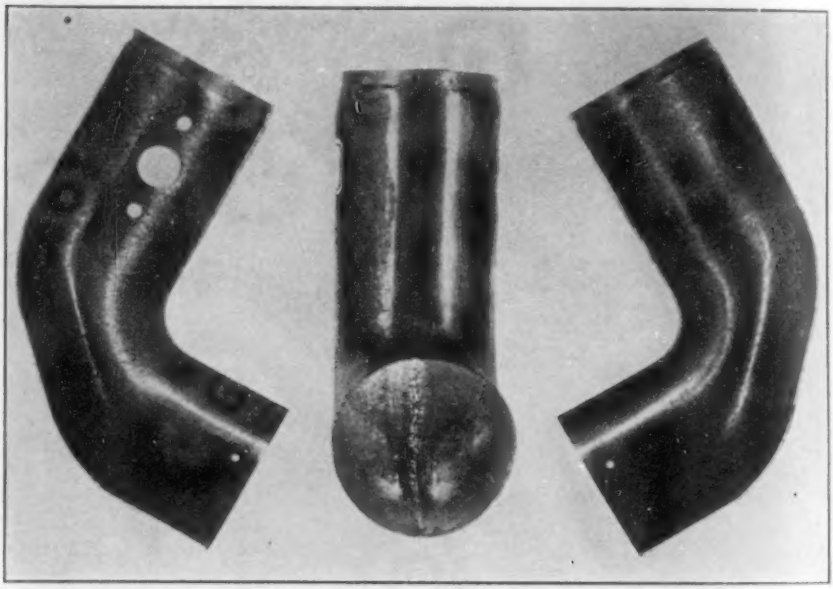


FIG. 10

since the advent of gas and arc welded pipe lines, the use of couplings is greatly diminished. But another difficulty immediately arose; namely, in certain sections of the country, even when the pipe line was ditched or buried, there was a wide range of temperature between noontime and midnight and between summer and winter and the expansion and contraction of the pipe was great enough to pull the pipe line in two in many cases. The solution to this was found in the use of what is known as an expansion coupling or expansion joint about every four lengths of pipe. These couplings are corrugated circumferentially so that they may be pressed up or expanded somewhat in the nature of an accordion. The expansion coupling may be welded on to every fourth length of pipe in the pipe mill before shipment, or as is often the case, the expansion joint is shipped separately and welded on in the field. These expansion couplings may be rolled up from corrugated stock with one resistance weld along the longitudinal axis, or, as is often the case, they may be made from two halves and two simultaneous resistance welds made, which makes a complete coupling. This expansion coupling is illustrated in

Fig. 9, which shows a sectional view of the coupling and the left hand end of pipe with the arc or gas weld laid down in the V, while the right hand margin shows an end view of the coupling with the location of the resistance welds required to manufacture it.

Blue annealed soil pipes for drains, sewers, etc., are beginning to be manufactured by the double resistance weld process, similar to those of the expansion coupling, except, of course, there are no corrugations on it.

Another instance of making pipe from two halves or shells is shown in Fig. 10, where the two stampings are welded together, two seams simultaneously into a manifold that is used in two of our highest priced automobiles. It is very common practice to weld standard pipe or tubing on to a steel casting or drop forging and fabricated parts of this kind

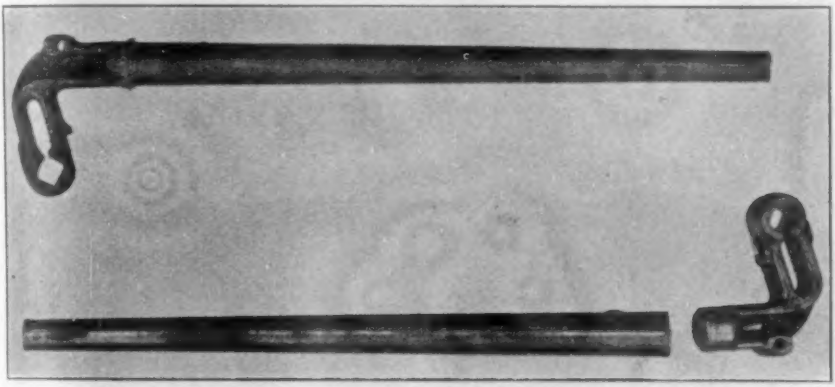


FIG. 11—METHOD OF FABRICATING AUTOMOBILE EMERGENCY BRAKE LEVER BY RESISTANCE WELDING

have numerous uses. One of these unusual jobs is shown in Fig. 11 wherein a fabricated tube is welded on to a drop forging to make an emergency brake lever for a very popular low priced automobile and doubtless many such parts are passing by you on every corner or block, every minute of the day.

Another common instance of welding standard and extra strong pipe to a steel forging or casting is shown in Fig. 12, which illustrates the modern method of manufacturing superheater pipe clusters for locomotives and for other uses. Doubtless we all recall our first boyhood glimpse into the fire box of a locomotive boiler where we observed a large number, several hundred in fact, of 2 in. diameter fire tubes. Many doubtless have not looked into the fire box of a modern locomotive, but in doing so they would discover anywhere from 56 to 64 large superheater tubes anywhere from 4½ to 6 in. diameter, among the 2 in. flues. In each of these superheater tubes, there are clusters of 1 in. pipe, the cluster sometimes consisting of two pipes with a return bend on one end, in the smaller superheater tubes, while in the larger ones the clusters consist of four pipes with return bends welded on to make a continuous circuit for the steam. A few years ago these return bends were tapped and the superheater pipes threaded and screwed into them,

but the very act of threading and tapping made a weak place on the end of the pipe, which often crystallized because of vibration causing leaks and sometimes breaks. Accordingly the railroads are now getting away from the tapping and threading and are resistance-welding the pipes on to the castings as shown in the figure.

The welding of these superheater pipes and return bends is done on the same welders as the safe-ending of the flues by changing dies, which are formed to suit the return bend. The welds are made by the flash process same as in safe-ending and there is no special preparation of the ends

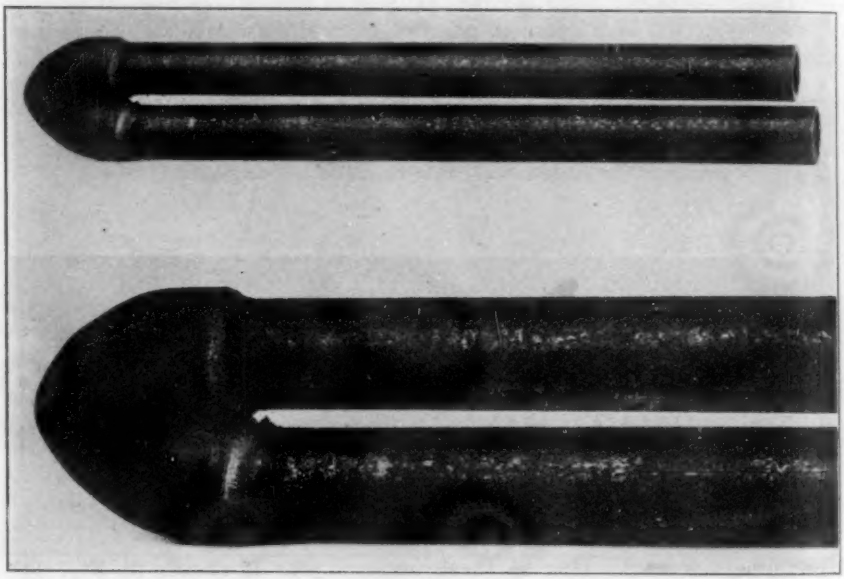


FIG. 12—SUPERHEATER PIPES WELDED TO CAST STEEL RETURN BENDS. TWO WELDS ARE MADE SIMULTANEOUSLY

of the work required, since the flashing burns off the irregularities and thus gives a good, true, even welding surface. Since the welds are made on a large welder, it enables them to make two superheater pipe welds at a time, thus giving a large production at a greatly reduced cost. It is customary to swage down all flues and tubes to a somewhat smaller diameter on the end that goes through the forward boiler head. This is done by heating the work in a gas or oil furnace and then swaging down by means of a steam or air operated hammer.

The electric flue welder has put the forge or furnace out of business as far as the welding is concerned, but until the present, it has still been necessary to retain small forges or furnaces to heat the ends of the pipe for a few inches for swaging down. To meet this requirement and to finally eliminate the noisy, dusty, hot furnace from the boiler shop altogether, a pipe heater has been developed which heats the ends of various size flues and tubes for swaging purposes. The first of these pipe end heaters to be built is so designed that two flues or tubes can be

heated simultaneously and either can be removed at any time without interfering with the other.

This pipe end heater is being further developed and in a short time will be ready to be placed on the market, at which time it is expected to entirely eliminate all forges and furnaces with their oil and gas piping, tanks, air lines, etc. The clamps on the pipe end heater are air operated and controlled by foot valves, leaving the operator's hands free to handle the work.

Practically all of the foregoing remarks apply to the particular type of boiler known as the firetube type, wherein the steam pressure is seldom over 350 lb. per square inch and the super-heated steam tem-

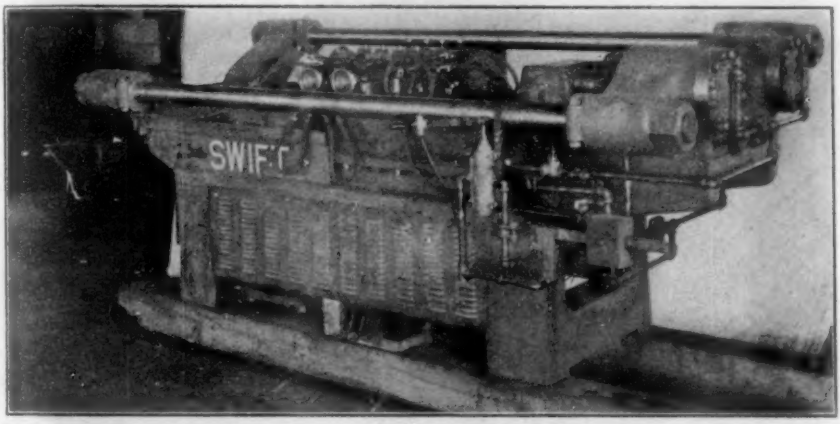


FIG. 13—HEAVY DUTY RESISTANCE WELDER FOR WELDING PIPE, OR ROUND SOLID STOCK UP TO 14 SQ. INCHES CROSS SECTION. NOTE RUGGEDNESS OF CONSTRUCTION THROUGHOUT

perature seldom above 500 deg. Fahr., usually much less. Electric resistance welding has been done in connection with the firetube type of boiler since 1912. It is interesting to note that water tube types of boilers are now being resistance welded. But there are several marked differences in the conditions under which they operate as well as differences in the types of welders used. Some of the special makes of water tube type boilers are tested at as high as 1500 lb. pressure per square inch at 900 deg. superheat. Now when it is remembered that 900 deg. Fahr. is hot enough to almost show a faint red color, it is easily realized that these welds must be irreproachable as far as strength and durability are concerned. Charcoal iron flues and low carbon steel flues are generally used for firetube type boilers, but in water tube type boilers a much stronger grade of metal is used. It is usually an alloy with a high nickel content and a chromium content of from 16 to 20 per cent and with several other ingredients to give desired qualities. The qualities most desired in this particular type tubing material are freedom from rust or corrosion, toughness, rigidity, density and freedom from laminae and porosity. The grain structure in these alloy tubes is so fine that it requires a welder with much larger pressure

cylinder so as to give a much greater maximum pressure at the instant of completing the weld.

In many cases it is impossible to find room on the welder sufficient for a single cylinder large enough to provide this enormous pressure, hence, it is often necessary to provide two or more pressure cylinders conveniently located on the welder so as not to interfere with the line of the work.

Fig. 13 shows one of the powerfully built heavy duty resistance welders for welding and pushing up water tubes. The pressure required to push up the hot pipe is often greater than the pressure required to push up a

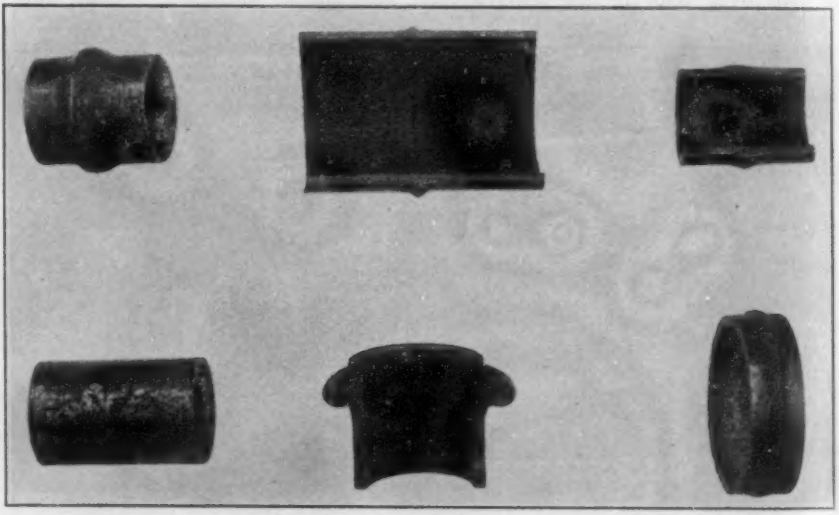


FIG. 14—SPECIMEN WELDS SELECTED AT RANDOM IN ORDER TO CHECK UP ON THE OPERATOR, AND KEEP HIM VIGILANT

solid steel bar of the same outside diameter as the pipe. This explains why it is necessary to use the rugged tie rods shown in the figure as well as why it is necessary to have the two large hydraulic cylinders working in multiple. There is a gap between the cylinders which allows the long lengths of pipe to lay in the hollow so as to line up with the dies and thus be welded in long continuous pieces, ready for bending. This type of welder weighs about 36,000 lb., is rated 550 KVA and will deliver 236,000 lb. push-up or squeeze at the weld with a hydraulic accumulator pressure of 2500 lb. per square inch. It is readily apparent that no set of contact clamps would be able to hold such enormous longitudinal pressure and the ones shown in the figures will clamp with a pressure of about 59,000 lb. only. Hence in work of this kind, it is always necessary to have either back up stops across the ends of the work or auxiliary hydraulic clamps that will exert a clamping pressure of around 300,000 lb. The auxiliary clamps are not shown in the figure, neither are the back up stops shown.

In order to secure the desired grain structure in the tubing at the

point of weld, it is necessary with some alloys to turn a hose upon the hot weld just the instant it is completed to quench the alloy and eliminate any local strains that might develop cracks later when the flues were in use. There is not sufficient time to remove the work from the welder for quenching, hence, it is necessary to make the welder waterproof so that the hose can be turned on the work in the machine itself. This requirement necessitates a practically new and radical type of construction to prevent the electrical part of the equipment from grounding, due to moisture.

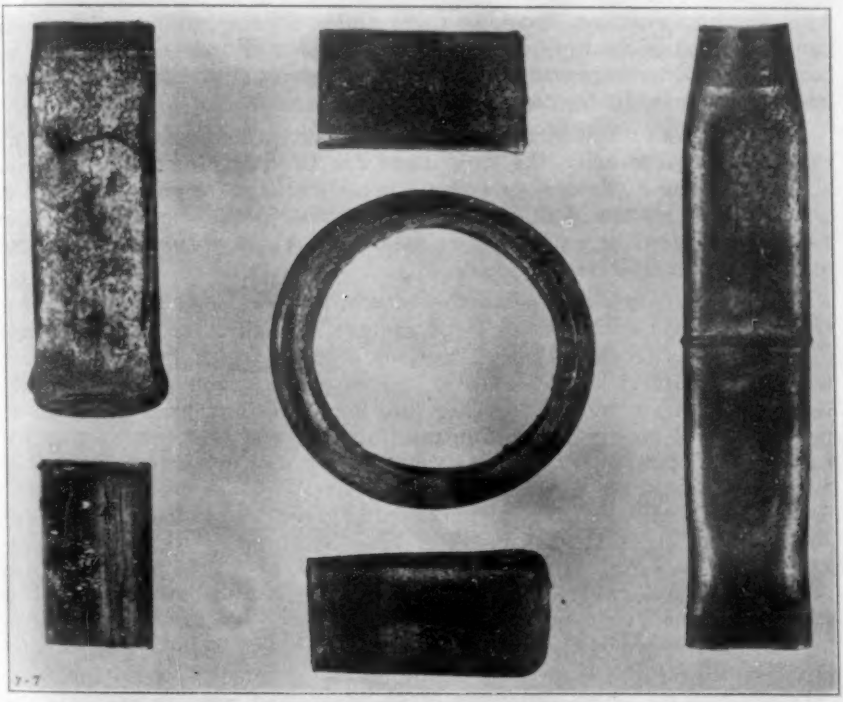


FIG. 15—SPECIMEN WELDS FROM WATER TUBES AFTER TESTING. NOTE THE PECULIAR SILVERY COLOR OF THE ALLOY

A statement is probably in order regarding the testing of these flues and tubes for both firetube and watertube types of boilers. During the first ten or twelve years of use of electrically welded flues for locomotives, it was customary to test every weld before putting the flue in the boiler. However, as the art of resistance welding flues and the types of welders themselves were improved, so few leaky welds were found that it became customary in some shops to assemble the flues and tubes in the boiler and then test the boiler as a complete whole. Then if an occasional leak was found, it was much cheaper to remove the particular flue or tube and replace it than to test all of the flues and tubes individually. However, some railroad shops continue to test every weld to be absolutely sure that there are no leaks before assembly.

The superheater pipe clusters are assembled and tested before they are installed in the superheater tubes. In order to test the efficiency of the operator himself and keep him on his metal, some shops cut out welds occasionally and inspect them carefully under a glass. They sometimes etch them and photomicrograph them. However, usually an examination with an ordinary magnifying glass is sufficient to secure the desired vigilance on the part of the operator. Such specimens are illustrated in Fig. 14 and an inspection of this kind is usually sufficient, in firetube types of boilers. In watertube types of boilers, however, the inspection is usually more elaborate and consists of bending specimens in a bending machine, crushing them under a press, pulling them in a tension testing machine and sometimes bursting some specimens by means of hydraulic pressure. Such specimens usually show a rupture at about 14,000 lb. hydraulic pressure per square inch.

Fig. 15 shows a few samples which have been tested, the center one by crushing longitudinally, the right hand one by flattening under a press, the bottom one by flattening under a press and then bending double, the upper left hand one was flattened four times in different planes. No failures occurred in any of these specimens which speaks well for the alloy itself as well as the welds.

One other branch of flue welding should be mentioned for although it sounds unimportant it shows large savings annually. It is the practice of reclamation or salvaging of sections of flues which in former years had been scrapped. Now, however, pieces of flues from 8 in. to several feet in length are welded together into long flues and used the same as new stock. The New York Central Railroad was the first of our big railroad systems to adopt this salvaging of broken or scrapped pieces of flues. Now, however, it is being done by several of our leading railroads. A medium sized railroad having from 1000 to 1200 locomotives and one shop, can usually take care of all of their safe ending, salvaging, super heater pipe welding, etc., with one large flue welder. On larger railroad systems, however, where they have a large number of railroad shops instead of one, it is customary to have at least one flue welder in each shop to save the transportation of the locomotive to the point where the welder is if there be but one welder on the system. Some of these far flung railroad systems which require a large number of welders each are the New York Central, Santa Fe, Chicago, Burlington and Quincy, Union Pacific, Missouri Pacific and several others.

The welding of medium size and large pipe lines in the field will no doubt always be done by means of arc or gas welding, since it is impossible to carry along a sufficiently large power plant to furnish power for a resistance welder for such work. Such a power plant would have to be 500 or 600 KVA capacity with gasoline motor driving a single phase generator and would also require a compressed air outfit. Such a device would have to be mounted on a caterpillar tractor and even then its availability would be limited by the topography of the country. It could not be used in swampy, wet land, nor in woods and forests, nor in rough, hilly or mountainous countries. The matter of building such a device was gone into carefully about two years ago with a view of making a resistance pipe welder that would travel along the pipe line and weld each

joint successively. It was found however, at that time that the cost would be excessive in proportion to the work that such a device would perform. Hence, it was never built and as stated before the welding of pipe lines in the field will undoubtedly be done in large measures by arc or gas welding equipment. We could continue indefinitely with descriptions and illustrations of other pipe and tube welding jobs but believe that those given herein will be sufficient to show the great importance and wide use of resistance welding in the circumferential welding of piping and tubing for all purposes. The fact that this process of welding is always done within the confines of a shop or factory, and not on the street, or on the frames of buildings where thousands of passers by may stop and gaze at it, leaves many people ignorant of even the existence of the resistance welding process. Perhaps future papers may show uses of resistance welding in other lines of industry.

Arc Welded Steel Motor Boats

By JOHN VAN HORNE†

THE Corps of Engineers, U. S. A., are now building a fleet of three arc welded steel motor boats for use as carriers and tow boats on the Mississippi River and its tributaries. This is the second fleet to be so constructed by the U. S. Engineers. The first fleet of seven was launched over a year ago and have been in continuous service ever since.

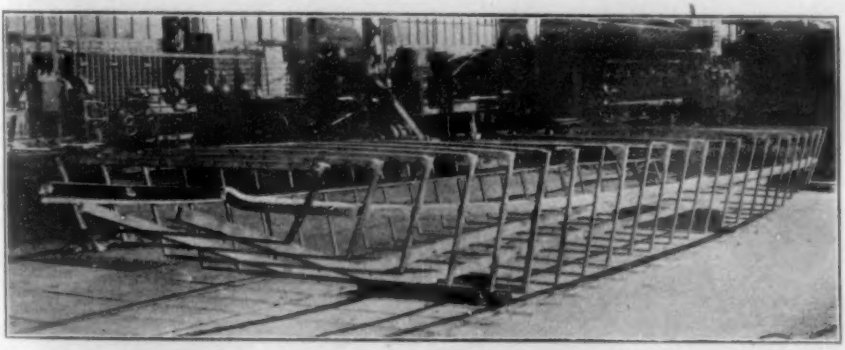


FIG. 1—SHOWING PARTIALLY COMPLETED STEEL SKELETON OF HULL FABRICATED ENTIRELY BY THE ELECTRIC ARC WELDING PROCESS

The launches are constructed entirely of steel, all permanent connections being made by the electric arc welding process. The overall length of each craft is 28 ft.; the breadth 7 ft.; and the depth 2 ft. 4½ in.; the freeboard, of course, varies with the load, the draught being very little when the boat is not loaded. The boats have flat bottoms, slightly stepped closed to the stern and have a rather sharp rise at bow effecting a broad, flat prow, similar to the seaplane type.

Some idea of the construction of these boats may be gained from the accompanying illustrations. Fig. 1 shows the partially completed steel skeleton of a hull. Each rib is made from one piece of channel iron,

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1½ in. x 9/16 in. x ¼ in., with exception of frame at rear end of forward bulkhead, which is of 1½ in. x 1½ in. x ⅜ in. angle iron. The two floor stringers are 3 in. x 3 in x ⅜ in. angles, punched and bolted in position to each frame, prior to arc welding. Angle iron stringers are also welded to each side of the channel frames. These stringers are also punched and bolted to the frames to maintain perfect alignment, until arc welded. Deck beams over the fore and aft bulkheads are 1½ in. x 1½ in. x ⅜ in. angles, arc welded directly to top ends of frames. Clamps formed from flat plate are arc welded to every other frame to carry the deck on both sides of the open cockpit.

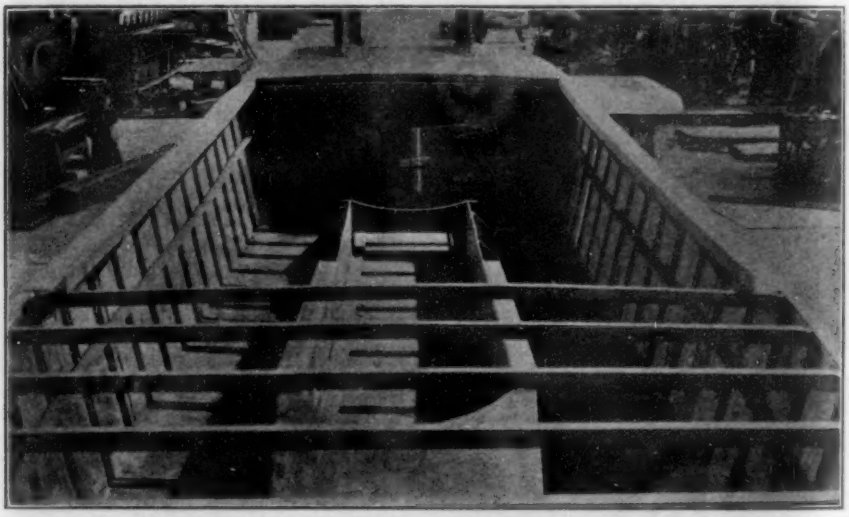

FIG. 2—INTERIOR VIEW LOOKING FORWARD FROM AFT BULKHEAD OF ARC WELDED, ALL-STEEL MOTOR BOAT

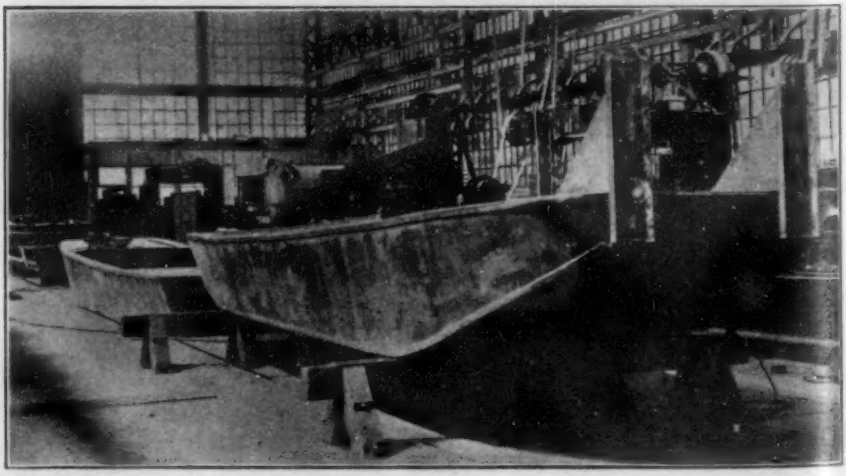

FIG. 3—STEEL PLATE ARC-WELDED TO AN ALL-STEEL FRAMEWORK MAKES A STRONGER, MORE DURABLE AND LEAKPROOF HULL

A view of the interior of one of the boats from the uncovered aft bulkhead looking forward is shown in Fig. 2. The engine base or mounting shown in this illustration is constructed entirely from ¼-in. steel plate, fabricated by arc welding and permanently joined to the floor or bottom of the craft and to the two floor stringers by arc welding. The engine base is braced on two sides by triangular pieces of steel plate with bottom edges crimped and arc welded to the bottom plates. The coaming around the cockpit consists of one piece of 2 in. x 2 in. x ¼ in. angle on each side and end. As can be seen in Fig. 2, the rear end of forward bulkhead is fabricated by riveting, so that it may be removed, when desired.

The bottom and side plates are joined to the frames by short fillet welds about 1½ in. long and approximately 7 in. apart. The bottom is of ¼ in. plate, the sides of 3/16 in. plate and the deck of No. 10 gage sheet

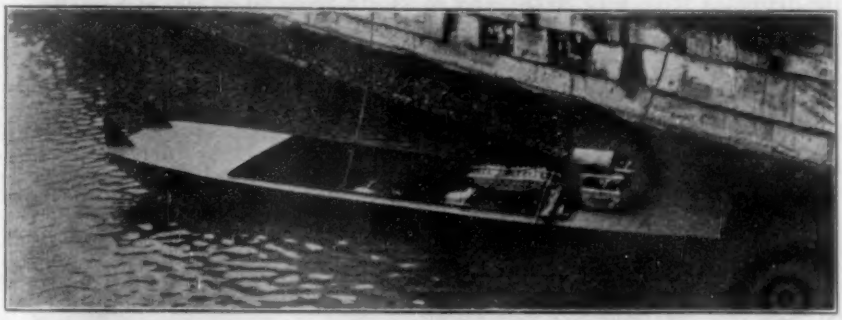

FIG. 4—THE COMPLETED HULL, WITH MOTOR MOUNTED, BUT BEFORE FITTINGS AND EQUIPMENT HAVE BEEN INSTALLED READY FOR TRIAL RUN

steel. Fig. 3 shows a completed hull, in foreground, on which can be seen the continuous welds along the edges of bottom side and deck plates. The bumpers at the bow of the boat are for pushing barges. They are constructed of 8 in. x 13¾ in. channels, braced by triangular pieces of 3/16 in. plate, and 2 x 2 x 3/16 angles attached to the deck and prow by arc welding.

Each boat is to be powered by a 125 hp. six-cylinder gasoline engine, equipped with a reduction gear having a ratio of three to one. With this arrangement the boats obtain an average speed of approximately 13 miles per hour when running light. Fig. 4 shows a completed hull with engine mounted, but before fittings and equipment have been installed, ready for a trial run.

The unique design and construction of these boats is a distinct tribute to the ingenuity and engineering skill of the Engineer Corps. The success of the design and construction of these arc welded all-steel motor launches, proved after a year's operation, marks a distinct step toward a new method of building power boats, which will undoubtedly affect the entire industry. Not only does the substitution of steel, the stronger and more enduring material for wood, mark an advance in small boat construction, but also the ability of the electric arc welding process to make a steel hull literally one piece of steel—which means a stronger, more durable craft, absolutely free from leakage.

Electric Welding of Field Joints of Oil and Gas Pipe Lines*

By Harold C. Price†

PRIOR to Sept. 1, 1928, there had never been constructed what might be termed a long pipe line with electric-welded field joints. Nevertheless, by Sept. 1, 1929, within the period of a year, more than 2500 miles of electric-welded lines have been completed. These lines vary in diameter from 6 to 20 in., and in length from 50 to 700 miles. Before Sept. 1, 1928, no such line had been constructed longer than 50 miles, and only one of nearly that length, a 40-mile 7-in. gas line in Louisiana. This was in reality the first pipe line to use electric-welded field joints. During the past year the following lines have been electric-welded by the Welding Engineering Co. alone:

Texas Pipe Line Co.—157 miles of 8-in. line from Corsicana, Tex., to San Augustine, Tex. (This was the first electric-welded oil line.)

Texas Pipe Line Co.—80 miles of 8-in. from Lafors, Tex., to Childress, Tex.

Texas Pipe Line Co.—39 miles of 10-in. from Monahans, Tex., to Jal, N. Mex.

Texas Pipe Line Co.—50 miles of 6-in. from San Antonio, Tex., to San Marcus, Tex.

Texas-Empire Pipe Line Co.—424 miles of 12-in. from Cushing, Okla., to Chicago, Ill.

In addition to the field welding mentioned above,[1] 250 miles of 12-in. line was electric-welded into double joints at the pipe mill at Indiana Harbor, Ind.

Equipment

Pipe—All of the pipe welded was equipped with the bell and spigot joint. About 70 per cent of the joints on the 8-in. line were equipped, in addition, with a welding dam on the spigot end (Fig. 1). Most of the pipe was electric-welded, with a carbon content of 0.20 to 0.30; the remainder of the pipe was lap-welded, with a carbon content of 0.06.

Welding Machines—It was decided to use 300-amp. generators on the firing line, or rolling welds, and 200-amp. generators on the bell-hole, or tie-in welds. Power for the large generators was furnished by six-cylinder motors, and for the smaller generators by four-cylinder motors.

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*Presented at Fall Meeting, A. W. S., Cleveland, September, 1929. Cuts loaned through the courtesy of the American Institute of Mining and Metallurgical Engineers.

†General Manager, Welding Engineering Co.

[1] The electric welding data contained in this paper were collected solely from the pipe lines mentioned.

The six-cylinders operated at 1500 r.p.m., and the four-cylinders at 1200 r.p.m. A 300-amp. unit, with a four-cylinder motor running at 1500 r.p.m., could have been obtained, but previous experience on welding tank roofs had taught us that constant use of a four-cylinder motor running over 1200 r.p.m. necessitated an unusual amount of repair. The fact that the engines would have to operate the welding machines at least 10 hr. per day under nearly constant load was taken into account.

FIG. 1—BELL AND SPIGOT PIPE WITH WELDING DAM

Welding Wire and Accessories.—The welding wire was a mild-steel, loosely coated rod. The welding leads consisted of 200 ft. of 00 rubber-covered cable. The other accessories were of the usual type.

Transportation—The problem of transporting the machines along the right of way was of great importance. The larger machines weighed

FIG. 2—CATERPILLAR TRACTOR MOVING WELDING MACHINE ALONG RIGHT OF WAY

nearly 3000 lb. On the first line constructed, each machine was placed on a wagon and drawn by a team, but on subsequent lines it was found that three teams could handle upwards to eight machines on the firing line. Eventually even these were dispensed with and a 2-ton caterpillar tractor was substituted, capable of moving as many as 11 machines throughout the day (Fig. 2). On the tie-in gang, however, it has been found advantageous to have a team for each one of the units.

The most efficient method of furnishing gasoline to the engine was to place a 55-gal. gasoline barrel on the same wagon with the machine and run a tube direct from this barrel to the vacuum tank (Fig. 3). This caused the minimum amount of refueling.

Operation

Organization—In constructing a long pipe line, the work is usually divided and assigned to two or more complete gangs, depending on the length of the line, and each gang completes its proportionate amount of

Fig. 3—Making Rolling Weld. Welding Machine in Background. Note Gasoline Barrel and Windbreak on Rear of Wagon

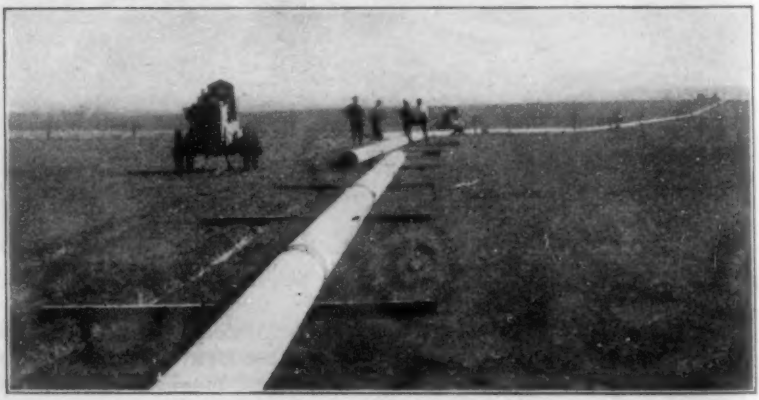

Fig. 4—Sections of Pipe Lined Up for Welders. Firing Line In Background

welding. Each gang is in charge of a welding foreman and is divided into two units, the firing-line unit and the bell-hole unit. The firing-line unit consists of from 6 to 12 welders, depending on the amount of pipe to be lined up and welded per day. Each welder has a helper, who chips or scales the weld and turns the pipe, as explained later.

For each gang there is a mechanic and a tractor driver, one of whom acts as a truck driver when necessary.

FIG. 5 — PIPE LINE AFTER SECTIONS HAD BEEN TIED IN AND PLACED OVER SKIDS PREPARATORY TO LOWERING INTO DITCH

General Procedure—The pipe is first lined up along the right of way on skids in sections averaging about six lengths each (Fig. 4). Thus, if the pipe were delivered in 40-ft. lengths, each section would average 240 ft., in which there would be five joints to be welded. These joints are all welded from the top by turning or rolling the pipe on the skids. Each welder is assigned to a section, and he completes all welds, in that section before moving ahead. Following the firing-line welders come the bell-hole welders, usually two or three, depending on the nature of the country and the speed with which the pipe is being put into the ditch. The pipe-line crew connects the previously welded sections over the ditch, placing them upon skids (Fig. 5). When the sections are connected, the bell-hole welders make the final weld. It is obvious that the pipe line cannot be turned as it is now in one continuous tube, therefore the bell-hole welders must weld completely around the pipe while the pipe remains stationary (Fig. 6). Naturally, only the best welders are put on the tie-in work.

FIG. 6—TIE-IN WELDER WELDING FIRST BEAD

Methods of Welding—The pipe ends are first cleaned of rust, dirt and grease, by using gasoline or kerosene and a wire brush. When the pipe is delivered with a protective coating, this coating or tar often gets on the ends of the pipe, and it is sometimes necessary to remove it either by scraping or burning it with a torch. The electric weld is applied

in two beads (Fig. 7). With the pipe lined up on skids, the welder welds the upper half of the first bead. He does this on each joint in the section successively. During this time the pipe is not being turned. This half also serves as a tack weld and keeps the pipe in line for subsequent operations. After the upper halves of the first beads are completed, the entire section is turned 180 deg. and the other half of the first bead is welded on each joint.

Each bead is covered by a certain amount of hard scale, which must be chipped off before the second or final bead is applied. The helper, therefore, follows the welder after each bead and chips off this scale with a hammer and chisel. This in no way delays the welder, as he is welding a new joint while the helper is scaling the old one.

After all the first beads are scaled, the section is ready for the second

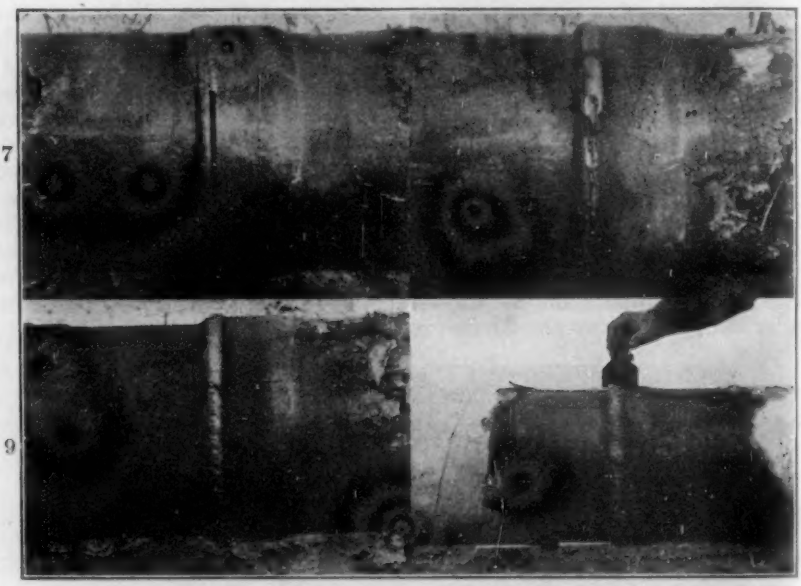

FIG. 7—BELL AND SPIGOT PIPE WITH WELDING DAM, FIRST BEAD PARTLY WELDED
FIG. 8—BELL AND SPIGOT PIPE WITH WELDING DAM, FIRST BEAD COMPLETELY WELDED AND SECOND BEAD PARTLY WELDED
FIG. 9—BELL AND SPIGOT PIPE WITH WELDING DAM COMPLETELY WELDED
FIG. 10—COMPLETED WELD ON BELL AND SPIGOT AND SPIGOT PIPE WITHOUT WELDING DAM, SHOWING GAGE USED BY WELDING INSPECTOR

or finishing weld. For this weld the pipe must be turned continuously. This is done by the helper with the usual chain tongs. The welding on the finishing weld is done on the top of the pipe only (Figs. 8 and 11). After each weld is finished, the welder will peen the final junction with his hammer, move on to the next joint and again make a complete weld, and so on until the whole section is completed. The finishing weld is not scaled (Figs. 9 and 10).

Procedure on the bell-hole weld is slightly different, for, as mentioned

above, the pipe cannot be rolled. A hole in which he will have room to operate must be dug for the welder in the ditch beneath the pipe. He starts the first bead at the bottom of the pipe and welds up one side to the top. He repeats on the other side of the pipe until the entire first

FIG. 11—WELDING SECOND BEAD. THE FIRST BEAD CAN ALSO BE SEEN

bead is finished. After this bead is scaled, he puts on the second bead in the same manner. Where the pipe-line crew is making good speed in tying in the sections, one welder will be assigned to putting on the first bead only, thus tying in the pipe quickly and delaying the pipe-line crew the minimum amount of time while the weld is being made. Sometimes it is necessary to use three tie-in welders. In this case one is used for tack-welding the joint as it is lined up by the pipe-line crew and the other two finish the weld. It is evident that each tie-in weld must be welded substantially before the pipe-line crew can add another section, particularly if there are any bends to be made in the line.

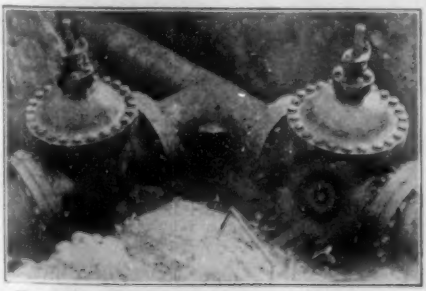

FIG. 12 — FLANGES ELECTRIC-WELDED TO 12-IN. PIPE

Welding River Crossings—Extra heavy pipe was used on the large river crossings and a proportionally heavy weld was applied. River

straps of two different designs were welded across the weld (Figs. 13 and 14). On the small rivers the pipe was welded in sections on shore and pulled across, being tied in to the line on the banks (Fig. 15). On the larger rivers, such as the Mississippi and the Missouri, the pipe was welded on the barge and lowered into the river after the welding of each joint (Fig. 16). Heavy river clamps were bolted over the weld before lowering (Figs. 17 and 18).

Welding Current and Welding Wire—On the firing line 3/16 in.

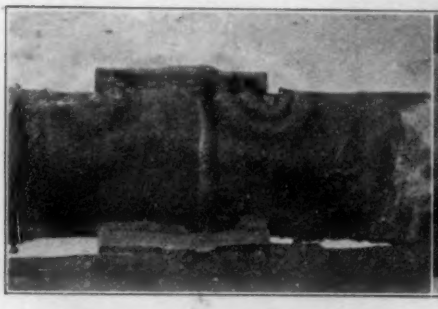

FIG. 13—REENFORCING STRAPS WELDED ON 8-IN. PIPE FOR RIVER CROSSING IN TEXAS PANHANDLE

FIG. 14—REENFORCING STRAP WELDED ON 12-IN. PIPE CROSSING ARKANSAS RIVER

FIG. 15—BARGE AND TUG DRAGGING WELDED SECTIONS ACROSS ILLINOIS RIVER

FIG. 16—WELDING RIVER PIPE ON BARGE CROSSING MISSISSIPPI RIVER

FIG. 17—RIVER CLAMPS TO BE BOLTED OVER WELDED JOINTS ON LARGE RIVER CROSSINGS

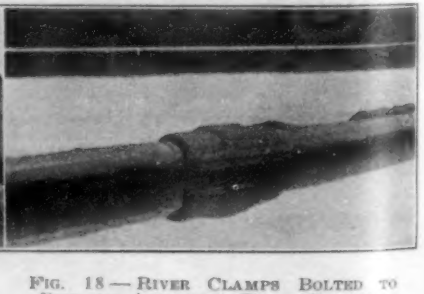

FIG. 18—RIVER CLAMPS BOLTED TO PIPE ON ARKANSAS RIVER CROSSING

welding rod is used for the first bead, with a current of 175 amp. For the second bead 7/32-in. or ¼-in. wire is used, with a current of from 200 to 250 amp. For the bell-hole weld, 3/16-in. wire is used for both beads.

Gasoline and Oil Consumption—The six-cylinder machines consume about 2 gal. of gasoline per hour, and the four-cylinder machines 1½ gal. per hour. The average amount of lubricating oil used on all machine is 0.8 gal. per day.

Specifications

The specifications called for a uniform weld of good appearance; the outside diameter of the weld to be approximately ⅛ in. greater than the outside diameter of the pipe bell, and the top of the weld not to be lower than the top of the bell at any point on the circumference. A

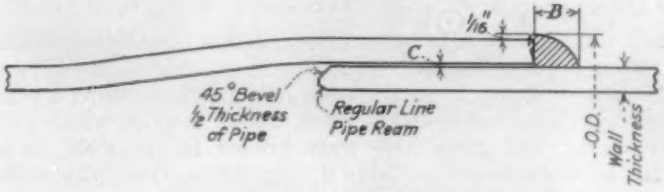

Fig. 19.—Dimensions of Weld for Various Sizes and Weights of Pipe.

Pipe Outside Diameter Inches	Weight per Foot, Pounds	Wall Thickness, Inches	*B* Inches	*C* Inches
6⅝	17.021	0.250	0.500	0.031
8⅝				
10¾				
12¾	40.000	0.303	0.500	0.047
12¾	65.415	0.415	0.520	0.040

sketch of the cross-section of the weld as applied to the pipe joint is shown in Fig. 19, together with a table of dimensions for various sizes of pipe.

Inspection

All welding is done under rigid inspection by the pipe-line owners and also by the welding contractors. There is an inspector on both the firing line and the tie-in gangs. Each weld is supposed to be inspected as it is made. Coupons are cut periodically with a milling machine from welds completed by each welder (Fig. 20). These coupons are merely slices of the welded joint. They are about ¼ in. thick, and cannot be used for strength tests. However, they do show a cross-section of the weld, and an indication of its size and penetration. Complete welds are also cut out at various times, and from these tests of

tensile strength are made. Any welds that do not measure up to proper specifications are immediately marked and rewelded. Where the bell and spigot joint is cut out for any reason, it is replaced by a split sleeve. The pipe is first welded with an ordinary butt weld; the sleeve is then slipped over this weld, and the split of the sleeve is welded. Both ends of the sleeve are then welded to the pipe (Fig. 21).

Results of Tests

Tensile Strength—Table 1 gives the results of tests of tensile strength made from coupons cut from 52 welds on the 12-in. line from Cushing to Chicago. The strength of these coupons averaged 50,870 lb. per sq. in. Practically all broke through the weld near junction with the bell, as shown in Fig. 22, which shows the cross-section of three coupons, with the pieces replaced after they were broken. They tested as follows: 67,500 lb. per sq. in.; 57,000 lb. per sq. in.; 53,900 lb. per sq. in. Only a few of the coupons broke in the weld near the spigot.

Tables 2 and 3 show the results of tensile tests made by pulling entire lengths of 12¾-in. pipe, each including a completed field joint. The sections noted in Table 2 were all cut out of the Cushing-Chicago line. All of these sections broke in the joint, except No. 10, which broke 2 ft. from the weld. The other nine were broken in the weld, or adjacent to it. The sections noted in Table 3 were taken from pipe welded into double lengths at the mill. Section 1 broke in the pipe and the other two sections in the weld.

Hydraulic—Hydraulic tests were made on all the lines as quickly as

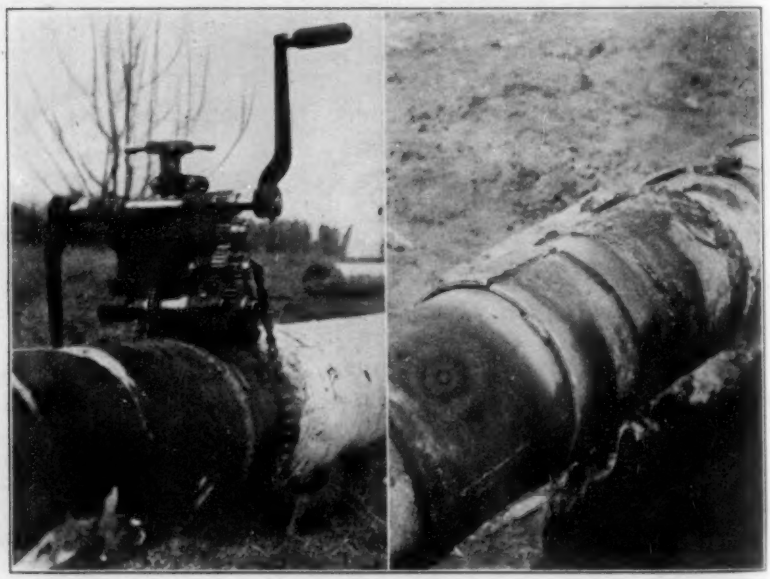

Fig. 20—Milling Machine Used for Cutting Coupons Through the Weld

Fig. 21—Type of Sleeve Used to Replace Weld Cut Out of Line

sections were completed and pumping arrangements could be made, using from 800 to 1000 lb. water pressure. Over 140,000 welds were made on the lines referred to, and the number of leaks discovered was practically negligible. Only two small leaks were found on the San Augustine-Corsicana line; about a dozen were repaired on the Lafors-

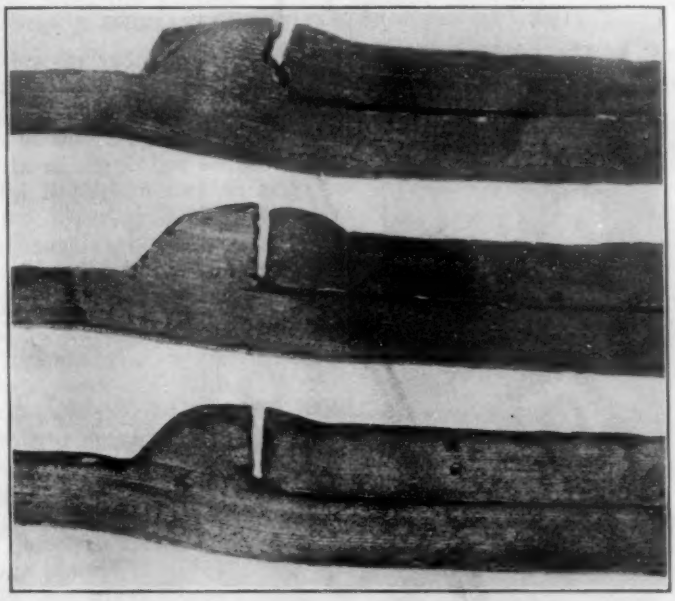

FIG. 22—CROSS-SECTION OF COUPONS CUT FROM WELDED JOINT FOR TESTS OF TENSILE STRENGTH, PARTS REASSEMBLED AFTER BEING BROKEN

TABLE 1.—*Tests on Tensile Strength of Coupons Cut from Electric-welded Field Joints*

Pipe Size, O.D., 12.75 In. Wall Thickness, 0.303 In. Wt. per Ft., 40 Lb. Carbon Content, 0.20 to 0.30

Amperage	Tensile Strength Lb. per Sq. In.	Amperage	Tensile Strength Lb. per Sq. In.
200	48,000	180	48,800
190	48,750	200	51,200
200	50,875	200	48,830
190	49,700	200	51,750
200	66,560	180	53,850
150	46,500	180	48,600
200	53,500	178	55,800
175	40,760	200	53,200
170	47,730	200	47,950
200	54,200	180	53,300
180	52,025		

Average tensile strength 31 additional tests (amperage not available), 47,276 lbs. Average amperage, 188. Average tensile strength, 50,870 lbs.

Childress line; not a leak was discovered on the 40 miles from Monahans to Jal or on the 50 miles from San Antonio to San Marcus. On the 354 miles of the Cushing-Chicago line tested at the time this is written only three leaks have been found, all of these being within a 23-mile section. All of the leaks mentioned were small pinhole leaks that were readily repaired.

Time and Speed of Welding Operations

The cost of the welding is determined by the number of welds that can be made by a welder per day. Where welding is done in a shop, this can be readily determined, but pipe lines cannot be laid in a shop and must be put down in all kinds of country and under all kinds of weather conditions. We will take the various jobs mentioned in the order in which they were built.

Fig. 23—Welding Near Hannibal, Mo., in Mid-Winter. Note Improvised Heater Directly Behind Welder

The San Augustine-Corsicana line was laid during the fall of 1928 in extremely rough country. The weather conditions were excellent until the last two weeks of operation. Under these conditions all welders, including both bell-hole and firing-line welders, averaged 15.3 welds per day. In computing the average number of welds made, bell-hole welders should not be taken into consideration because in tying in pipe there are so many delays possible for which the welding is in no way to blame. The real speed of the welding can be determined by computing what the firing-line welders are doing. On this 8-in. line, the firing-line welders averaged 21 welds per day.

The 10-in. line from Monahans to Jal was laid in level country, and during fairly clear weather. The greatest delays were caused by severe sandstorms, which made work impossible for about 30 per cent of the time during the last two weeks. The average speed of the firing-line welders on this line was 19.9 welds per day.

On the San Antonio-San Marcus line, with the exception of 15 miles, the country was fairly level, but the weather was extremely wet, which caused considerable loss of time and reduced the average number of welds below that of the two former lines. The average per man was 17.7 per day on the firing line.

The Cushing-Chicago line ran through both level and hilly country. Work started Feb. 1, 1929, when the ground was frozen (Fig. 23). Spring thaws started early in March, so that it was necessary to move machines through 15 in. of mud, when possible (Figs. 24 and 25). Fol-

lowing the thaw, the heavy and continuous rains arrived, and it was not until June 15, and in some places even later, that it was possible to weld pipe on dry ground. The welding speed on the 12-in. pipe for the firing line from start to finish averaged 10.3 welds per man per day. When good weather arrived, the average rose to 13 welds per day.

As to the actual time of making a complete weld on 12-in. pipe 0.303 in. thick, the average for the rolling welds has been found to be 30 min. and the bell-hole welds 45 min. The time for electric welding of other sizes of pipe of the same thickness has been in direct proportion to the diameter.

24

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FIG. 24—SAMPLE OF SPRING MUD IN MISSOURI. CATERPILLAR OF LINE-UP MACHINE COMPLETELY SUBMERGED
FIG. 25—PULLING WELDING MACHINE THROUGH HEAVY MUD

Throughout the welding of these lines there have always been certain times when conditions were ideal, when some welder would set an extremely high record for one day. The maximum number of welds per 10-hr. day for one man has been: 6-in., 38 welds; 8-in., 40 welds; 10-in., 28 welds; 12-in., 25 welds.

COMPARATIVE COSTS

As mentioned, it is difficult to give reliable costs for welding various sizes of pipe, either by the electric or any other method, as the costs depend on the speed of the welding, and the speed depends on the nature

of the country and the condition of the weather. Because of this feature, it would be misleading to compare the costs of electric welding with those of gas welding unless two pipe lines of the same kind of pipe were laid in the same locality at the same time, and even then, for accurate comparison, the cost-keeping system would have to include identical items. The company with which the writer is connected has never attempted to weld pipe lines by the acetylene method, and the figures given to us by various contracting companies have varied to such a

TABLE 2.—*Tests on Tensile Strength of Electric-welded Pipe Joints (Entire Joint Pulled on Testing Machine)*

Pipe Size, O.D., 12.75 In. Wall Thickness, 0.303 In. Carbon Content, 0.20 to 0.30. Open-hearth Steel

Test Number	Tensile Strength, Tons		Efficiency of Welded Joint, Per Cent
	Pipe	Welded Joint	
1	386.05	310	80.30
2	431.86	325	75.95
3	419.21	278	66.31
4	346.98	278	80.12
5	349.74	318	90.92
6	366.05	320	87.42
7	441.58	285	64.54
8	413.21	252	60.97
9	498.07	275	64.24
10	342.88	324	94.49
Average.....	392.57	296.50	75.52

TABLE 3.—*Tests on Tensile Strength of Elecric-welded Pipe Joints (Entire Joint Pulled on Testing Machine)*

Pipe Size, O.D., 12.75 In. Wall Thickness, 0.375 In. Carbon Content, 0.06. Open-hearth Steel

Test Number	Tensile Strength, Tons		Efficiency of Welded Joint, Per Cent
	Pipe	Welded Joint	
1	410.57	363.00	88.41
2	401.90	348.00	86.58
3	386.78	332.00	85.83
Average.....	399.75	347.66	86.97

great extent that we have been unable to use them. However, one of the largest oil companies, a pioneer in the gas-welding of pipe lines, has been kind enough to compare its costs with ours on a parallel basis. We divided the costs into four items as follows:

1. Labor, as applied to each welder. This included, for gas welding, the welder, helper and teamster, and for electric welding, the welder, helper, mechanic and tractor driver.

2. Generation, including for the gas welders, acetylene and oxygen, and the cost of transportation of these, with containers, to and from the job; for electric welding, gasoline and oil.

3. Welding wire.

4. Depreciation.

All other items, such as supervision and overhead, were considered even, and thus eliminated in the comparison. The results obtained were as follows:

1. *Labor*—Electric welding costs are 25 per cent greater than gas.

2. *Generation*—Electric welding costs are 61 per cent less than gas.

3. *Welding Wire*—Electric welding costs are 40 per cent less than gas.

4. *Depreciation*—50 per cent per year was allowed on the machinery for electric welding, and it was conceded that there was no depreciation on the generators and equipment for gas welding.

Considering only the items listed, the electric-welded joint shows a total saving of 22 per cent in comparison with the gas-welded joint. We believe that these figures are fairly accurate, and as accurate as can be determined at the present time.

Conclusion

Considering the great amount of pipe that has been electric-welded within the period of only one year, it is natural that we believe that during that time much progress has been made in the welding of pipe lines. Those who have had the privilege of being connected with the electric welding of these lines have had much to learn, and what they have learned in this past year should certainly encourage them for the future. We believe and predict that the electric welding of pipe lines has only started, and that with improved machinery and improved welding rods the time for welding each joint will be greatly reduced, and the cost of the welding reduced in proportion.

Acknowledgment

The writer wishes to thank the executives of The Texas Pipe Line Co. and The Texas-Empire Pipe Line Co. for their cooperation and assistance in the development of many of the methods described above, and also for their courtesy in furnishing many of the data and photographs contained in this article.

Fatigue Tests on Drums and Shells†

By H. F. Moore*

ADVENT of higher pressures in steam boilers has necessitated the use of plate material of increased thickness for the shells. This has appreciably affected the problems of design and manufacture of boiler drums. In the United States, riveted drums are in service for steam pressures up to approximately 800 lb. per sq. in., which seems to be about the limit for this type of construction. For steam pressures of the order of 1500 lb. per sq. in., solid or forged drums have been used. For pressure vessels other than steam boilers, drums have been built with welded seams in quite heavy plates.

In view of the highly satisfactory service obtained from riveted drums, it has seemed desirable to have a direct experimental comparison of strength between riveted drums and other types of drums, and also to make tests of drums with riveted seams using plate material of greater tensile strength than that of ordinary boiler plate.

Realizing that an ordinary static pressure test to destruction gives only a limited measure of the value of the construction used, the Babcock & Wilcox Co. has for some time been making tests on drum shells of various types under repeated applications of pressure. These experiments are still in progress, but it seems desirable to present certain results already obtained for information, with the distinct understanding that the conclusions here given are tentative and that further results may be expected as the tests proceed.

The apparatus described in this article and the methods of test developed have been designed and developed by the laboratory force of the Barberton plant of the Babcock & Wilcox Co. The writer has served as a special consultant in the conduct of the fatigue experiments.

The specimens tested were full size boiler drums, or shells of full size drum diameter (3 ft. to 3 ft. 6 in. inside). The expense and time necessary for preparing such specimens and making the tests were so great that comparatively few specimens have been tested. In making ordinary fatigue tests, six or more small specimens of each metal to be tested are subjected to various stresses, and usually some tests for each metal are run to at least 10,000,000 cycles of stress. In this manner it is possible to determine the "endurance limit" for nearly every metal below which the metal in question will withstand an indefinitely large number of cycles of stress without fracture.

This method was not feasible for the tests of full size drum shells. It was decided to determine the relative length of endurance of specimens (that is, the number of repetitions of stress to failure), although this is

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†Reprinted from *Iron Age*.

by no means the best criterion of strength under repeated stress. However, in the ordinary service of a boiler the cycle of stress on the shell is repeated at most a few thousand times, and the stress is not reversed, varying from zero to a maximum with slight fluctuations near the maximum stress. Thus it was feasible to run the tests to numbers of cycles of stress greatly in excess of the number of cycles to be expected in the normal service of a boiler.

It is a well-known fact that a very slight change in the stress, if it is above the endurance limit of a metal, will make a large change in the number of times that stress must be imposed to cause fracture. From

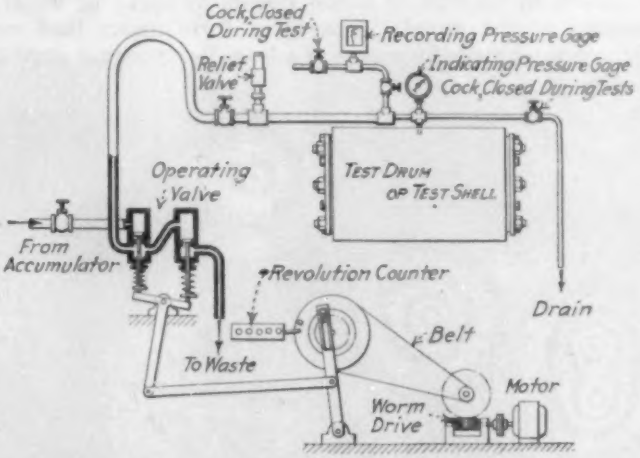


FIG. 1—DIAGRAM OF APPARATUS FOR REPEATED STRESSES ON BOILER SHELLS AND DRUMS

his general experience with fatigue testing, the writer believes that a decrease of 33 1/3 per cent in the stress might mean an increase in "life" of about 25 times. It would seem, then, to be a conservative statement that if, under test, a boiler drum shell withstood without fracture 150,000 cycles of stress varying from zero to a stress 50 per cent above working stress, it might be concluded that a similar drum shell made of the same material would not fail by fatigue under normal length of service at working stress.

The tests herein described were planned on this basis, applying repeated cycles of stress 50 per cent above the working stress to specimen drum shells, and noting the length of life before fracture, and the location and character of the fracture.

A diagram of the apparatus used is shown in Fig. 1, and photographs of the set-up at the Barberton shops of the Babcock & Wilcox Co. are shown in Figs. 2, 3 and 4. Water under a pressure of 1600 lb. per sq. in. is taken from the accumulator-controlled pressure mains of the plant. This water goes through a reducing valve to produce the pressure desired in the test, and then through a set of mechanically operated valves (Fig. 3), which alternately admit water under pressure to the test drum shell and

allow the pressure in the drum shell to be relieved through the exhaust pipe. These mechanically operated valves are driven through link work by an electric motor whose speed can be varied, and the link work is fitted with a revolution counter which indicates the number of cycles of pressure applied. Several sets of such valves are operated by the one motor, and several test drum shells can be tested at one time. The pressure applied to each specimen is shown on a Bourdon gage directly attached to the specimen, and is also measured on a recording pressure gage. The equipment was ordinarily operated so as to give six repetitions of stress per minute.

In addition to observations to detect incipient fracture in a test shell (usually shown by leakage or a fine stream or spray of water), careful measurements of the minute changes of form under load were made. Some of these were made by means of a 2-in. Berry strain gage and others

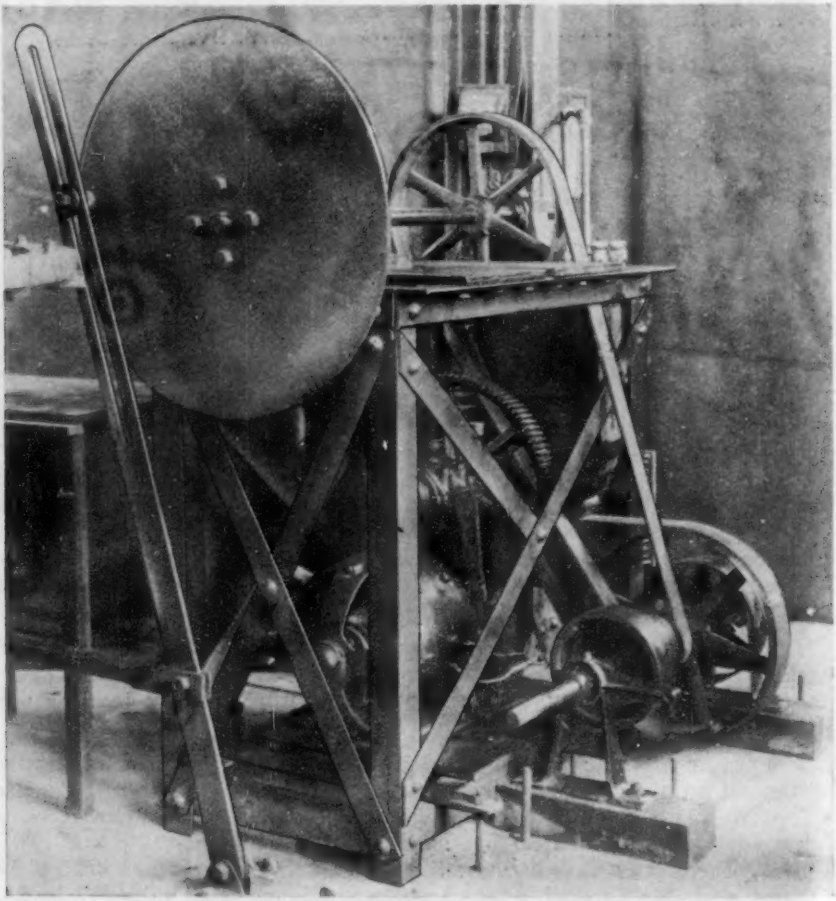


FIG. 2—MOTOR DRIVE AND LINK MOTION FOR OPERATING HYDRAULIC VALVES

by means of micrometer dial gages attached to a framework supported from the test drum shell. The principal utility of the measurements of minute strain was to determine whether any marked permanent distortions of the specimens occurred as the tests progressed.

Two types of test specimens were used. The first, which was used for riveted construction, consisted of a drum shell with standard heads riveted to it. This type of specimen is referred to as a "test drum." The second type of specimen consisted of the test shell with an inner shell of smaller diameter, leaving an annular space between the two shells into which water under pressure was admitted. Fig. 5 shows the general arrangement of this type of specimen, which is referred to as a "test shell."

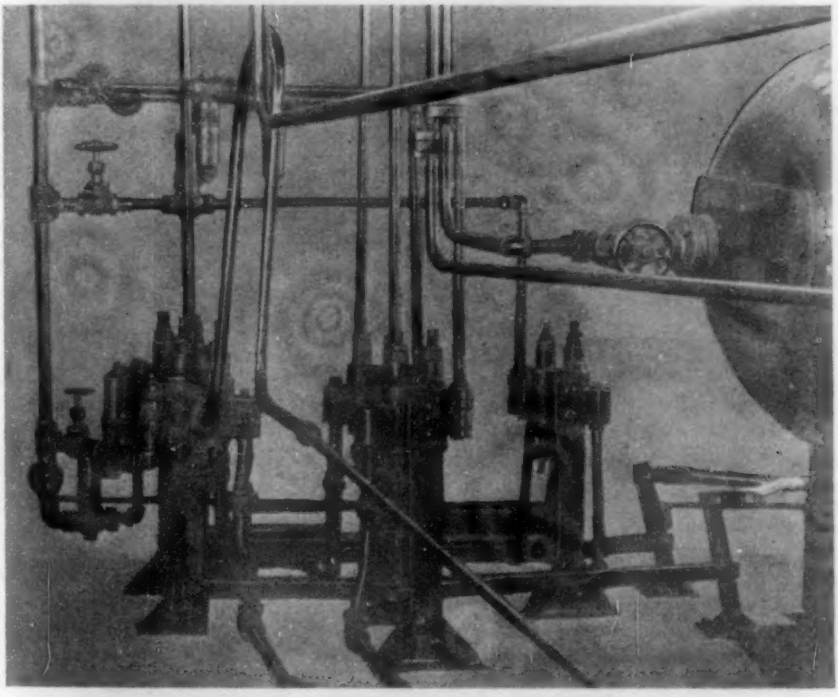


FIG. 3—HYDRAULIC VALVES FOR TESTING SEVERAL DRUMS SIMULTANEOUSLY

Drums and Shells Tested

One of the specimens was a manganese steel test drum. The plate material in this specimen showed an analysis of 0.29 per cent carbon, 1.95 per cent manganese, 0.025 per cent phosphorus, and 0.036 per cent sulphur. Physical properties were: yield point 83,500 lb. per sq. in., tensile strength 106,500 lb. per sq. in., elongation in 8 in. 16 per cent, and reduction of area 36 per cent. The plate material for the remaining specimens was ordinary carbon steel boiler plate, and both the chemical

analysis and the physical properties showed thoroughly satisfactory results for the metal in each specimen.

The designation of each test specimen, ruling dimensions of each test specimen, the type of joint, the range of test pressures and resultant

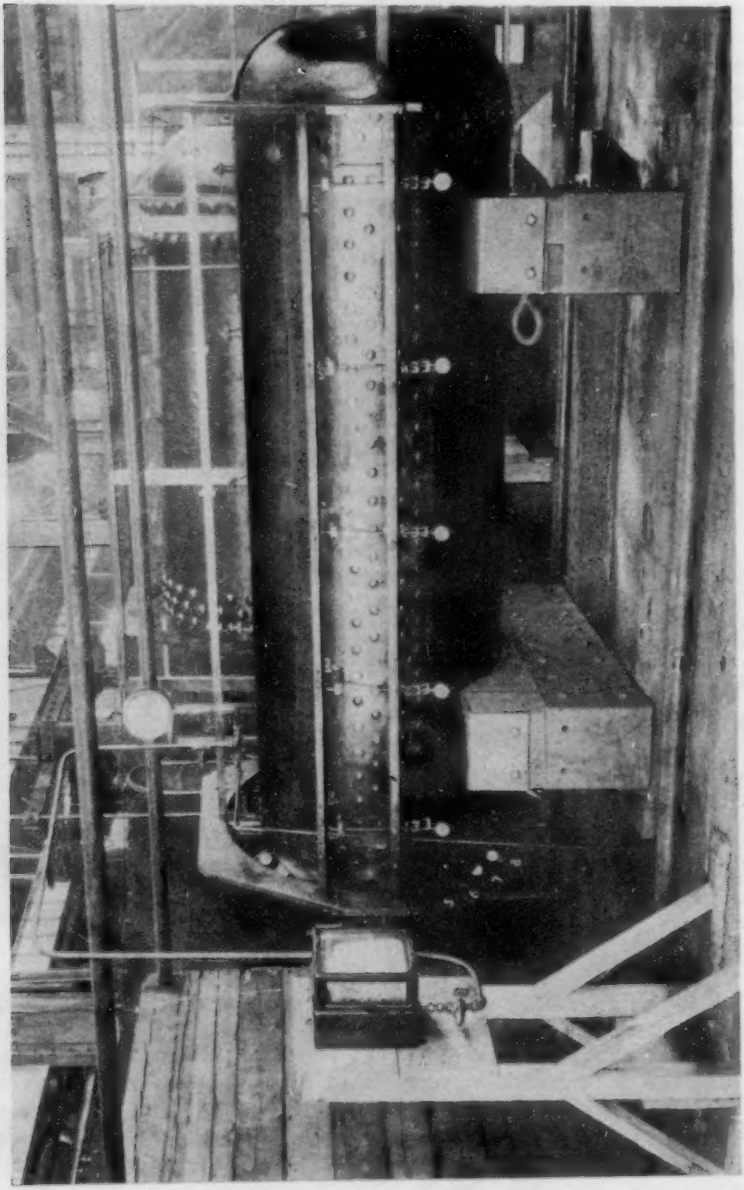


FIG. 4—TWO DRUMS UNDER TEST

TABLE I—SUMMARY OF TEST RESULTS

Specimen	Shell Dimensions: Inside Diameter, In.	Shell Dimensions: Plate Thickness, In.	Longitudinal Seams	Efficiency of Joint, Per Cent	Lb. per Sq. In.: Max. Allowable Working Pressure	Lb. per Sq. In.: Range of Test Pressure[a]	Lb. per Sq. In.: Range of Tensile Hoop Stress[a]	Number of Cycles of Pressure Applied During Test	Failure
Manganese steel test drum, riveted	35 5/8	1.00	Two at 180 deg.	71	838	0–1,260	0–31,500 0–22,400[b]	130,225	Failure in drum head below manhole
A.S.M.E. standard drum, riveted	42	2.00	Two at 180 deg.	80	838	0–1,260	0–16,500 0–13,200[b]	1,013,840	No fracture
Arc welded test shell "A"	42	2.00	One	100[c]	1,047	0–1,570	0–16,500	5,530	In longitudinal seam near middle of length at junction of base metal and weld metal
Arc welded test shell "B"	42	2.00	One	100[c]	1,047	0–1,570	0–16,500	417,381	At 1/2-in. tap hole for gage, not at weld
Arc welded test shell "C"	42	2.00	One	100[c]	1,047	0–1,570	0–16,500	561,984	At 1/2-in. tap hole for gage, not at weld
Arc welded test shell "D"	42	2.00	One	100[c]	1,047	0–1,570	0–16,500	435,883	At 1/2-in. tap hole for gage, not at weld
Forged test shell	42	1.875	None	100	1,047	0–1,570	0–18,000	446,950	At 1/2-in. tap hole for gage

[a] Test pressure 1.5 times working pressure. Maximum stress under test pressure is 1.5 times working stress.
[b] The higher of the two ranges is the range of computed stress through the line of rivets; the lower of the two ranges is the range of computed stress in the shell away from the riveted seam.
[c] The efficiency of the welded joints is taken at the nominal value of 100 per cent.

computed stresses, the number of cycles of stress for fracture, and the character of the fracture, are given in Table I.

Comments on Each Test.

The manganese steel test drum was cold riveted. Slight trouble with the gaskets at the manholes occurred during the first few hundred cycles of pressure. Between 3000 and 4000 cycles slight leaks appeared along the buttstraps and in one head seam. No leaks developed at the rivets. At 7100 cycles it was necessary to stop the test to replace a gasket on one manhole cover, and at this time the head seam was calked. The test

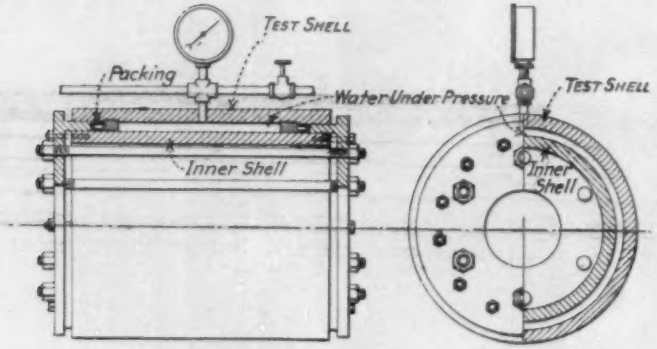


FIG. 5 — (ABOVE) TEST SHELL FOR DETERMINING FATIGUE STRENGTH OF WELDED OR FORGED CYLINDERS

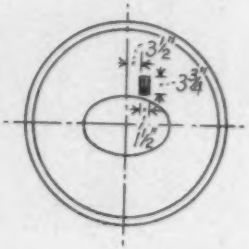
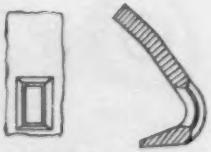


FIG. 6 — SKETCH OF ORIGINAL CHECK IN DRUM HEAD AND METHOD OF REPAIR



was resumed, and after 45,000 cycles of pressure a slight leak appeared in both head seams. One of these leaks increased until at 65,000 cycles it was necessary to stop the test and recalk this head seam. Test was resumed, and at 92,000 cycles one manhole cover was replaced by a heavier cover. After 130,225 cycles a leak had developed near the manhole opening which was evidently a fracture. The test was stopped and examination showed a crack about 3¾ in. long located as shown in Fig. 6. The metal around this fracture was removed, a thin plate fitted into the hole and the rest of the opening filled with weld metal. The test was started again, but after 143 additional cycles of pressure the drum

head split violently, as shown in Fig. 7. Examination showed a slight fracture extending into the edge of the shell. Strain measurements showed considerable variation, but no outstanding evidence of permanent distortion except in the immediate vicinity of the location where the original crack developed.

The A. S. M. E. standard drum (that is, one designed and constructed according to the provisions of the boiler code) was riveted in the usual way. After 25,000 cycles of pressure had been applied minute leaks developed along the lower edge of a buttstrap and in both head seams.

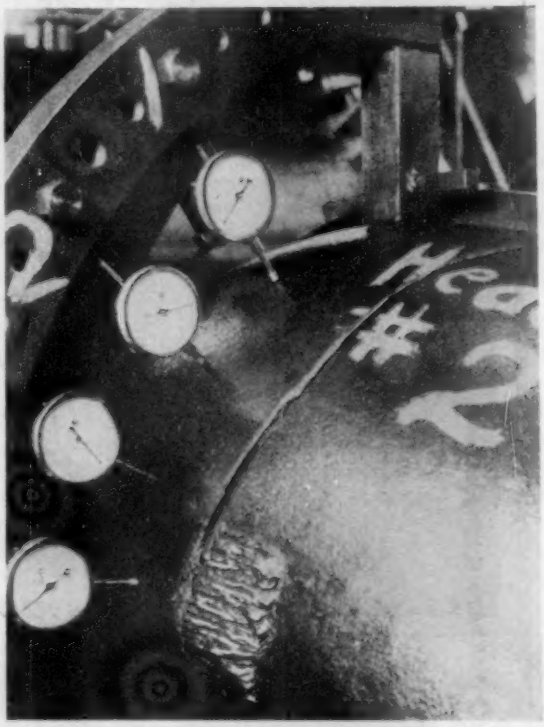


FIG. 7—LONG CRACK SKIRTING EDGE OF WELDED PATCH IN DRUM HEAD OF MANGANESE STEEL

After 32,000 cycles the test was stopped and the seams calked. The test was resumed and after 431,000 cycles a very minute leak (about one drop per minute) developed at the bottom of one head seam. At 629,000 cycles slight leaks had developed along the lower edge and the end of one buttstrap. The test was stopped and the joints recalked; thereupon the test was resumed, a total of 1,013,840 cycles of pressure was applied without developing any fracture. The measurements of strain gave no evidence of permanent deformation during the test.

Arc welded test shell "A" is shown, in diagram, in Fig. 5. The stresses set up were practically pure hoop tension. Arc welding was done by

FIG. 8—PLUG SPECIMEN CUT FROM ARC WELDED TEST SHELL "C" WHERE BROKEN AT TAPPED HOLE FOR PRESSURE GAGE. AT LEFT IS VIEW OF OUTER SURFACE OF PLATE; IN CENTER IS THE SIDE OF THE PLUG SPECIMEN, AND AT RIGHT THE FRACTURE SHOWS OPEN TO A CONSIDERABLE DISTANCE ON EACH SIDE OF THE HOLE

hand, using ordinary bare welding wire. After 5530 cycles of pressure, fracture developed in the welded seam at the junction of base metal and weld metal.

Arc welded test shell "B" is also shown, in diagram, in Fig. 5. The seam was arc welded by hand, using a processed electrode (covered electrode). After 163,000 cycles of pressure, the longitudinal seam of the *inner* shell of the test apparatus fractured. This inner shell was repaired and the test continued. After 417,381 cycles, the outer shell fractured, not in the weld, but at the tapped hole where the pressure gage connection was made. This is a point of stress concentration, and its significance is discussed later. During the test the strain measurements showed no sign of permanent deformation.

Arc welded test shell "C" is shown, in diagram, in Fig. 5. The seam was also welded, using a processed electrode. After 160,000 cycles of pressure the packing of the joint between inner and outer shells became loose. The test was stopped and the packing replaced; thereupon the test was resumed, and after 561,984 cycles the outer shell cracked at the gage connection (a ½-in. pipe thread). The failure was similar to that for arc welded test shell "B," and is shown in Fig. 8. The crack barely reached through to the outer surface, but was several inches long on the inside. During the test the strain measurements showed no evidence of permanent deformation in the steel test shell.

Arc welded test shell "D" was a duplicate of shell "C" in construction, type of welding wire used, and method of testing. After 435,883 cycles of pressure failure occurred at the gage connection, as in the case of shell "B" and shell "C."

The forged steel test shell was a forging without any longitudinal seam. After 20,000 cycles of pressure the inner shell of the test apparatus cracked in the longitudinal seam; it was repaired and the test continued. After 446,950 cycles the outer shell fractured at the pressure gage connection in a manner very similar to the fracture for arc welded test shells "B," "C" and "D." The strain measurements showed no evidence of permanent distortion.

Stresses Concentrated at Holes

It is obvious that, until many more tests have been made, nothing in the nature of final conclusions can be drawn as to the fatigue resistance of boiler seams. However, in view of the very meager amount of data concerning the behavior under repeated stress of such seams, and of welded joints in general, these few test results seem worthy of attention.

In the case of the test shells which fractured at the tap hole for the gage connection, it is to be noted that according to the theory of elasticity such a hole would cause a stress-intensification at its edge amounting to three times the computed stress in the plate. The practical effect of such holes, as judged by repeated-stress tests, seems to be less than this theoretical value. Haigh and Wilson[1] have made tests of specimens of structural steel under cycles of tensile stress varying from zero to a maximum, and they report a reduction of strength due to a hole of only

[1] (British) Association for the Advancement of Science, 1923. Report of Section "G."

a very slight amount for structural steel, although later tests showed a larger reduction for harder steel with a hole in it. Tests at the University of Illinois[2] on specimens of soft steel subjected to cycles of reversed bending show a reduction of strength of about 50 per cent due to the hole. In this connection it is to be noted that the "A. S. M. E. standard drum" (line 2, Table I), which did *not* fracture, had such a tapped hole in its outer shell. However, owing to the allowance for efficiency of the riveted joint, the stress at the tapped hole (which was some distance away from a riveted seam) was only 13,200 lb. per sq. in., as compared with 16,500 lb. per sq. in. for the stress at the riveted seam.

A fair value for endurance limit of boiler plate steel under reversed bending is 26,000 lb. per sq. in. For cycles of stress varying from zero to a maximum it may be expected that the value of endurance limit will rise to about 39,000 lb. per sq. in.[3] This would indicate that the practical stress-concentration factor at the tapped hole in the case of the shells tested lay between $39{,}000 \div 13{,}200$ and $39{,}000 \div 16{,}500$, that is between 2.95 and 2.36. Possibly the rather rough finish left by the tap, and the irregularities of outline due to the threads, may make this factor higher than would have been the case for a smooth drilled hole.

It should be noted that the riveted drum specimens stood up well under repeated cycles of pressure, and it seems in order to inquire why the stress-concentration at the rivet holes was not more in evidence. In the case of the "A. S. M. E. standard drum," the grip of the rivets on the plate may have spread the stress in the vicinity of the rivet hole. There also may be a factor affecting strength of riveted joints similar to the effect reported by R. R. Moore,[4] later checked by tests at the University of Illinois, who found that a *single* groove in a test specimen reduced the fatigue strength much more than did a series of grooves. Possibly a series of holes acts in a similar fashion.

During the tests some corrosion of the metal was noted, but there is no apparent evidence that corrosion fatigue played an important part in the test results.

The results of these few tests do seem to furnish a basis for three conclusions:

(1) Welded joints in test drum shells have been made which do not weaken the fatigue strength of the shell as much as does the tapping of a hole for a gage connection.

(2) Welded joints in test drum shells have been made which withstood cycles of stress varying from zero to a value 50 per cent above the allowable working stress for more than 400,000 cycles. This is at least 50 times as many cycles as would be developed in the normal life of a boiler.

(3) The strength of a welded seam under repeated cycles of pressure is greatly affected by variation of welding practice. It is evident that, if it is expected to obtain welded joints at all resistant to repeated stress, it is very necessary to develop and maintain good, uniform welding practice, and carefully inspect the welding.

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[2] Bulletin 152, Engineering Experiment Station, University of Illinois, pages 25 to 34.
[3] Moore and Kommers "The Fatigue of Metals," page 185.
[4] Proceedings, American Society for Testing Materials, Vol. 26, Part II, page 225 (1926).

Large Steel Building Completely Oxy-acetylene Welded*

By H. H. Moss†

UTILIZATION of oxy-acetylene welding in place of riveting in the construction of the steel framing for a building erected by Union Carbide and Carbon Research Laboratories, Inc., in the plant of Union Carbide Company at Niagara Falls, N. Y., marks a stage in the development of structural welding by the oxy-acetylene process, wherein this method advances to embrace the major industrial structure. It is believed that this is the largest structural building frame that has been so constructed, and the first of its character to be fabricated and erected under usual procedures of construction.

Description of Building

The building is a mill type having a single aisle 75 ft. wide between column centers, by 260 ft. long, arranged in thirteen 20 ft. bays, by approximately 42 ft. 5 in. to the lower chord of trusses. Mezzanine operating floors extend along the entire westerly side of building, single stage in bays 1 to 11 and three stage in bays 12 and 13. These floors are 27 ft. wide and 11 ft., 9 ft. 6 in. and 9 ft. 6 in. in vertical elevation. Fig. 1 shows the building as viewed from the south while the welders were completing the erection of the framework. Fig. 16 shows the structure from the northwest. The main and first mezzanine floors are served at present by a full span, 10-ton capacity traveling crane, although the craneway is designed to support a 20-ton crane. Mezzanine details are shown in Figs. 12, 13 and 14. A standard gage railroad siding enters the building through car doors provided in the south end, to facilitate handling of equipment and operating materials. The building is unattached, contains approximately 300 tons of steel and will be used exclusively for research purposes.

This is the first of a series of welded building structures in contemplation for construction by our company. This type of building was selected for the initial project primarily because it contained a miscellany of structural joints and offered opportunity for a more general application of structural welding than would have obtained in the pure multi-story type of structure. In execution, it would provide structural welding data for a number of industrial types of building structures.

Preliminary Considerations

Although, from a gas welding standpoint, this building is in the class of experimental cases wherein the time factor is nearly always of secondary importance, urgent need for the finished building demanded prompt

*Presented at October meeting, New York Section, A. W. S.

†Engineer, Development Dept., Linde Air Products Co., New York.

execution of all construction phases of the job. General plans of the building, including typical framing, had been prepared but as the framing was designed for riveted construction, a restudy of the framing designs was necessary before the job could be placed in the hands of shop draftsmen for detailing.

Decision on the part of the management to handle the welded steel in a manner similar to that which would have been followed, if riveted, had a dual objective:

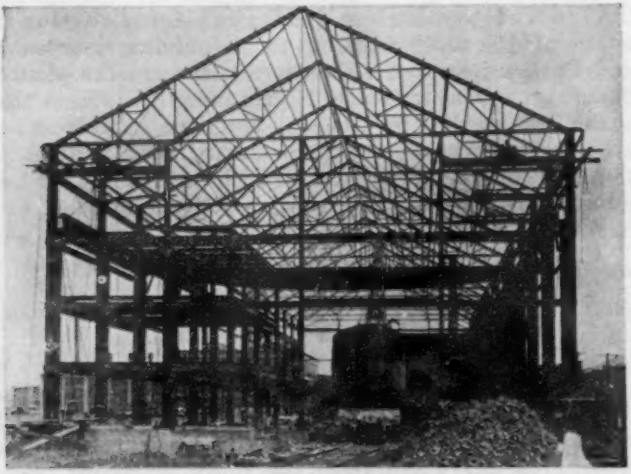

FIG. 1—COMPLETING OXY-ACETYLENE WELDED STEEL FRAMEWORK

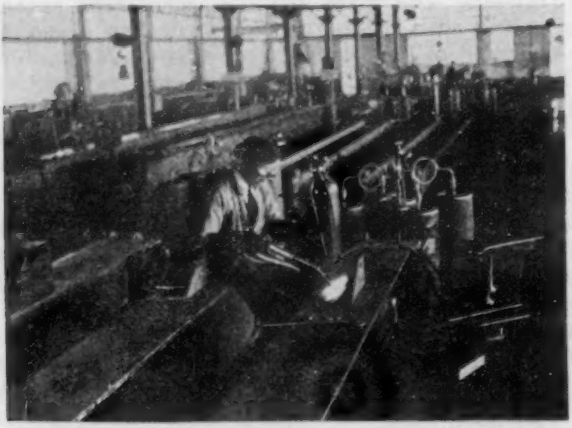

FIG. 2—WELDING CRANE GIRDER KNEE BRACE

1st—Provision of proper construction facility and consequent maximum construction speed.

2nd—To obtain practical experience with gas welding when applied to this class of building structure under conditions having a semblance of routine production and erection character.

It was recognized, however, that the cost for this first case would probably be higher than that for a riveted job, as there had been no previous opportunity for fabricators or erectors to develop experience with this method of structural welding. This would necessitate a period at

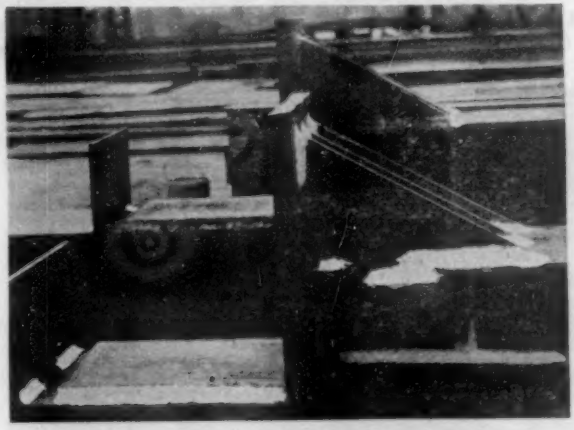

FIG. 3. DETAIL OF CRANE GIRDER SEAT

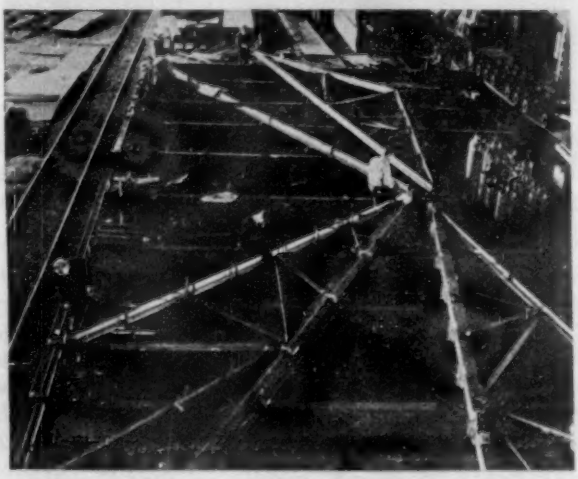

FIG. 4. FABRICATION OF TRUSSES

the beginning of shop operation and field erection, subject to a certain amount of experimentation and modification of methods, and during which the welding rate would not be up to production speeds. It was further decided that the job be manned by welders at large, rather than by the company's trained operators, thus providing an opportunity to determine the feasibility of employing the welder at large for work of this kind.

As the welding was to conform to the requirements of the American

Welding Society's Structural Welding Code, completed in substance at the time, the above procedure would be of greater value than if company welders had been used.

The American Bridge Company agreed to undertake to fabricate the steel and at their suggestion the work of producing the designs for the welded construction was placed in their hands. In this they were to be assisted by the Development Section of The Linde Air Products Com-

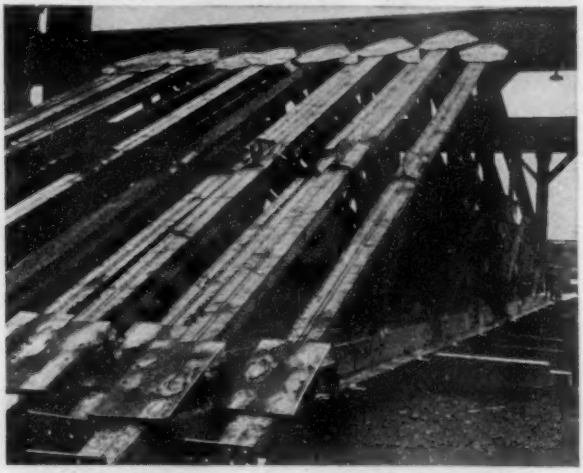

FIG. 5—HALF-SECTIONS OF TRUSSES READY FOR SHIPMENT

pany and Union Carbide Engineering Department. It was further arranged that The Linde Company would undertake to obtain and qualify the necessary welders and aid in the supervision of shop welding. General views of the fabricating shop are shown in Figs. 2 and 4.

Design

In general, the designs for welding developed for this job were characteristic of the lap method of assembly of parts, utilizing the fillet type of weld. This is particularly true for the truss web members and for beams and girder connection details. Exceptions to this method were made at the heel and ridge joints of the trusses where a combination of fillet and butt welding was utilized and in the anchorage details for all principal columns. Liberal use was made of the C. B. (Carnegie Beam) beam and column sections. Through the elimination of built-up columns and girts commonly used in this type of building by utilizing rolled single sections and by placing bolt holes for assembly purposes in details, wherever possible, the major tonnage had only to be oxy-acetylene cut or milled prior to transfer to the welding skids for jigging and the attachment of details. As the roof purlins and chord bracing would ordinarily not be riveted in place, welding of this material was therefore omitted.

The main building columns are composed of two milled C. B. sections, one 24 in. x 12 in. x 7/16 in. x 100 lb. and one 14½ in. x 12 in. x ½ in. x 95 lb., offset at the elevation of the crane beam seat. These sections were

shop spliced by fillet welding 1 in. x 10½ in. x 3 ft. 1 in. plates on the face of column flanges, the inner plate being cut to straddle the web of the 24 in. C. B. section below the web joint. The base plants for these and end columns were delivered to the job with necessary anchor bolt holes ahead of framing so they could be set and grouted before the columns arrived. Anchorage for the columns was effected by means of double extra heavy pipe lugs, double fillet welded to the edges of the column flanges, through which the anchor bolts were passed and secured

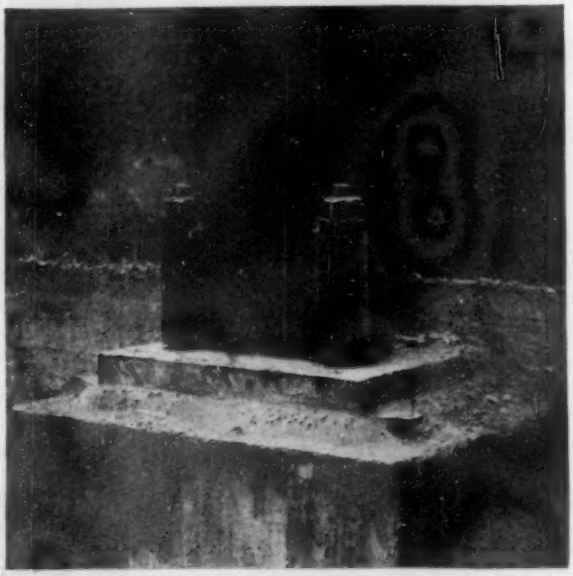

FIG. 6—COLUMN ANCHORAGE

by the nuts. One-half inch round washers were used to seat the nuts to the upper milled edge of the lugs. The columns are capped by suitable bearing plates fillet welded thereto along the outer face of flanges only. In these plates bolt holes were provided for field assembly with corresponding holes in bearing plates welded to the under section of bottom chord of truss.

For the crane beam seats, it was decided to use bracketed plates, as these beams offset the 24-in. column, preventing direct bearing.

The connecting details on columns for girts, lintels and beams were made up of clip angles providing landing seats and side connections where necessary. These details, provided with assembly bolt holes, were welded to the columns, thus avoiding shop work other than milling and welding on the column sections.

The configuration of the trusses, which are 75 ft. x 19 ft., is a modified compound Fink of ¼ pitch, having the principal compression struts normal to the lower chord. This permitted the welding of trusses in half sections in the shop, as the modification brought the dimensions of the sections within shipping limits.

These trusses are designed to sustain, in addition to the dead load, a snow load of 25 lb. per sq. in., a wind load of 15 lb. per sq. ft. applied normal to the top chord, and three concentrated loads of 2000 lb. each at the center and the two principal joints of the lower chord, calculated

FIG. 7—TRUSS LOWER CHORD SPLICE WELDED IN FIELD

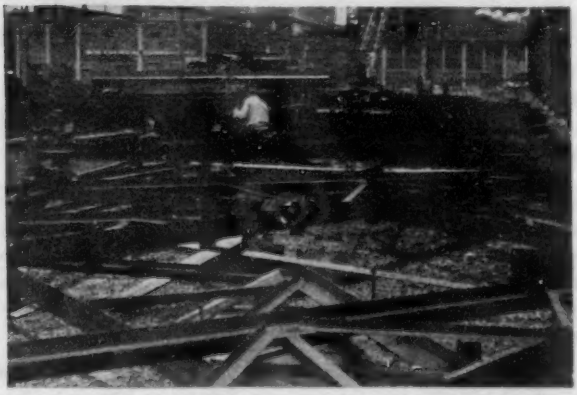

FIG. 8—WELDING TRUSS SECTIONS TOGETHER

as hoisting loads. The upper and lower chords were developed from 16 in. C. B. 50 lb. and 14 in. C. B. 38 lb. sections by splitting them longitudinally. This produced T-sections with sufficient leg length to receive the web members without using gusset plates. Where these T-sections meet at the heel of truss the webs were butt welded (in shop) and at the ridge the flanges were butt welded (in field). At the heel, the upper chord flange was extended to engage the flange of the lower chord. The web and knee-brace members are composed of angles permanently secured by $\frac{3}{8}$-in. fillet welds.

For the floor beams use was made, wherever possible, of the flat flanges of the C. B. section for landings, welded connection details being provided for beam webs only. In designing the connections for beam and girder, allowance has been made for a possible 25 per cent increase over present floor loads.

FIG. 9—COMPLETED TRUSS RIDGE CONNECTION

A unit tensile stress of 16,000 lb. per sq. in. governs for base metal design and for weld metal design 11,300 lb. per sq. in. for shear and 15,000 lb. per sq. in. for compression through the net throat of fillet and butt welds.

Shop Fabrication

From a fabricating standpoint, the job progressed with good dispatch. At the outset, the rate of production was somewhat slow, due to welders' unfamiliarity with this class of work, but after the first few members and assemblies were welded, the welding rate per hour increased steadily and little difficulty was experienced from then on in maintaining alignment. Each welder was required to pass qualifying tests as recommended by the American Welding Society Code, and by competent inspection the quality of the shop welding was kept at a high average.

The trusses were assembled in jigs secured to the welding skids in which the truss members were clamped for welding. Simple clamps were developed by the fabricating company for the shop assembly of details. For this job oxygen and acetylene were supplied from groups of manifold cylinders placed at convenient points in the welding shop.

Shop welding was completed in about six weeks. In all, ten welders were employed, starting with two the first week, four the second week, six the third week and an average of nine thereafter until completion.

The erection contract called for bolt assembly only.

The field welding was carried on under the local organization of Union Carbide Co. Three of the shop welders were brought to the building to do the field welding for the purpose of completing their experience. The first field welding consisted of joining the half truss sections on the

ground. Bolts at the splice and ridge joints permitted bolt assembly of these sections, which was done by the erector. The assembled trusses were laid flat on blocking along one side of the main aisle, each truss lapping the other in such a manner so that the welders could get at the joints. This procedure required one-half of the welding on these trusses to be

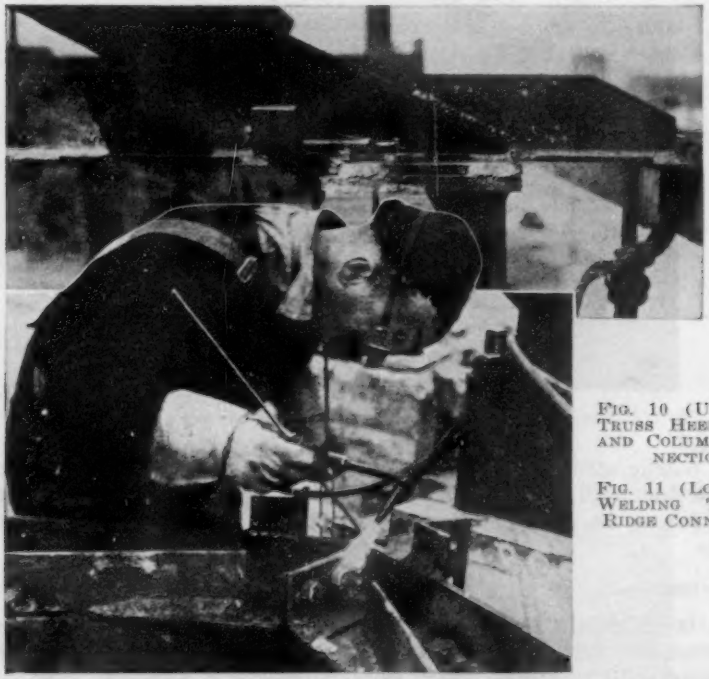

FIG. 10 (UPPER)—TRUSS HEEL JOINT AND COLUMN CONNECTION

FIG. 11 (LOWER)—WELDING TRUSS RIDGE CONNECTION

done overhead, and demonstrated the feasibility of joining welded trusses in the field in a manner similar to that if the joints had been riveted.

Costs

During shop fabrication time studies were made of the rate of welding developed by different welds. After the welders had become familiar with the production sequence and had opportunity to improve their skill in the production of specification welds, the average production was 320 in. per day of 9 hr. for the specified 3/8-in. fillets and 245 in. per day for the 5/8-in. fillets.

The term "specified 3/8-in. fillets" is used because in reality they were larger, it being difficult for the welders to hold the smaller dimensions of the 3/8-in. weld on this class of material. Therefore, an adjustment is necessary in calculating rates in order to give consistent data.

The total theoretical amount of welding taken from the drawing is:

3/8-in. fillet welds	2483 ft.
5/8-in. fillet welds	344 ft.
3/8-in. open butt welds	69 ft.
5/8-in. single vee butt welds	35 ft.

Had advantage been taken of all the experience gained on this job, it is estimated that the shop welding would have required about 1100 man-hours. This indicates an expected average tonnage per welder per 9-hr. day of 1.67 tons for the material upon which shop welding was done. This totalled about 203 tons, the balance of 95 tons requiring either field welding or field bolting only.

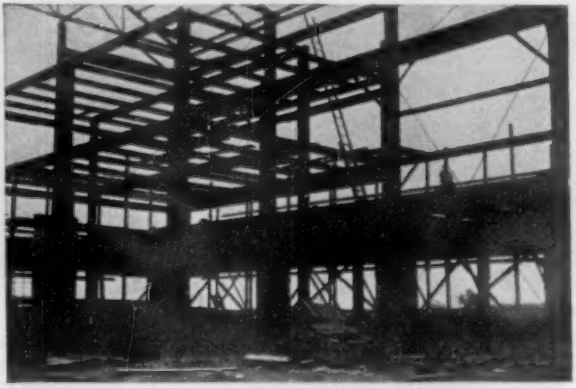

FIG. 12—THREE-STAGE MEZZANINE SECTION

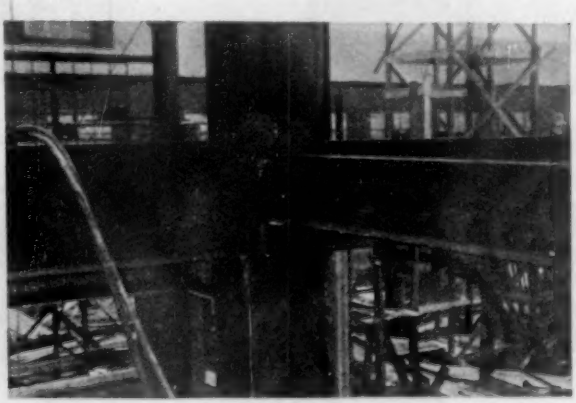

FIG. 13—BEAM AND GIRDER CONNECTIONS AT COLUMN

From shop data, between 200 and 225 cu. ft. of oxygen and 185 to 208 cu. ft. of acetylene may be taken to represent probable gas consumption per average ton of shop welded steel. Calculations of welding rod consumption allowing for oversize welds and a slight rod loss, indicate 7.5 to 8 lb. of welding rod per average ton of shop welded steel. The smaller fillet welds, which were actually about ½ in., require about 0.6 lb. rod per linear foot of weld; the ⅝-in. fillets 0.85 lb.; the ⅜-in. open butt welds 0.5 lb.; and the ⅝-in. single vee butt welds about 2.2 lb. per linear foot of weld.

From the above data, it has been estimated that the shop welding cost should average not more than $20 per net ton of shop welded steel or $13.70 per ton on the basis of total job tonnage. This figure includes all setting-up expense in the welding department and an 85 per cent overhead on labor, but is exclusive of the cost of milling, splitting, shearing or cutting, punching and handling expense.

FIG. 14—WELDING FLOOR FRAMING IN MEZZANINE SECTION

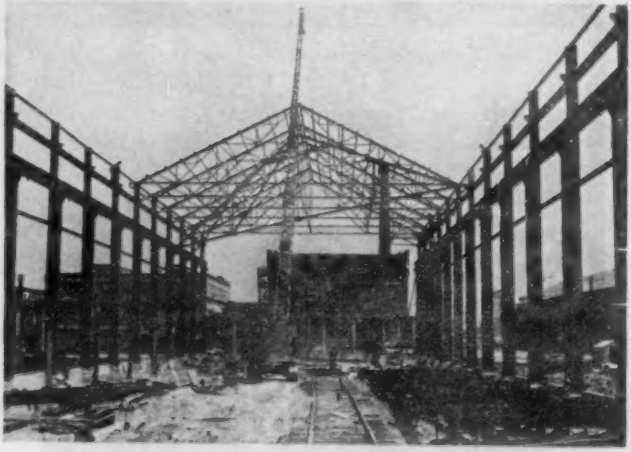

FIG. 15—RAISING ONE OF THE COMPLETED TRUSSES INTO POSITION

This cost will be offset by an amount representing the erected cost of the steel saved by welding instead of riveting. The saving in weight in a structure of this character is at least 10 per cent of the weight of a similar riveted structure. For this particular job, the saving amounts to approximately 66 2/3 per cent of the shop welding costs, bringing the net shop welding cost for welded construction within commercial ranges.

As more experience is gained in this work, further economies will be obtained. These will come through greater utilization of the strength provided by welded construction, improved designs for connections, lower detailing expense, more efficient handling of welding equipment through-

out the shop, standardization of set-up for welding, and by increased production rates of welding.

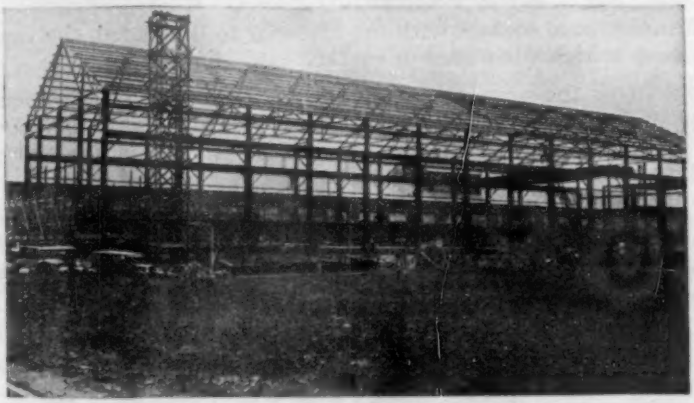

FIG. 16. READY FOR THE WALLS

It is expected that the field erection cost for a welded structure of this type will be about the same as for riveted construction. For the pure multi-story type a lower cost will probably be realized.

Electrodes for Electric Resistance Welding

F. E. ELGE†

THE use and importance of electric resistance welding is rapidly increasing, especially in the automotive industry. Machinery for mass production of welded parts has been developed and the cost of finished goods decreased, while a better quality is obtained. However interesting it may be to discuss the details of welding machines, we have limited the scope of this article to a short discussion of one important factor, that of a suitable material for electrodes such as fixtures, holders, jaws, etc.

Few manufacturers of welding machines operate their own non-ferrous foundry for making of such parts and the average factory, not having time for experiments, or wanting to take chances, will very likely not use their machines to the best of their advantage. The practical usefulness of an idea is, to a great extent, limited by the physical properties of the construction material available. As a basis for further discussion and comparison between different metals, we will first try to point out the desired properties and relative importance under various circumstances.

In all types of resistance welding, the duties of the electrodes can be summarized as follows:

> To conduct the electric current and transmit mechanical pressure at temperatures higher than room temperature.

†Hudson Motor Car Company, Detroit.

The electrical conductivity must be high and the temperature coefficient low in order to transport current with the least cross section and temperature rise.

To insure a good contact with the material to be welded, the electrodes should have a high resistance to surface oxidation. .

Transmitting the pressure, the electrodes are subjected to compression and repeated impacts and their useful life is proportional to their *hardness* and *resistance to impacts*. A high resistance to wear is necessary to insure perfect alignment and constant surface of electrical contact.

The magnetic permeability is of great importance, the electrodes must be non-magnetic under all circumstances, even after an accidental overheating. If the permeability is high, considerable current losses and heating will result from the magnetic induction.

As the mechanical properties as well as the electrical conductivity decrease at an increase of temperature, the operating temperature of the electrodes should be kept as low as possible. It partly depends on the metal used for electrodes which shall have a high specific heat and a high heat conductivity, thus diminishing the effect of localized overheating and increasing the cooling effect of water, when artificially cooled.

The temperature of the electrodes also depend on the welding temperature and the electrical conductivity of the material to be welded, its shape and size, and its projection from the electrodes, i.e., viscosity at welding temperature. These external factors are always given and may have some influence on the choice of material for electrodes.

Now let us consider metals and alloys available for electrodes used to their best advantage. Due to high electrical conductivity and non-magnetism copper is extensively used in this connection. It has, however, a serious disadvantage in poor mechanical qualities, especially at high temperatures. In many places it is replaced, but where the current density is very high, such as electrodes in spot welders, wheels in seam welders, it is difficult to find anything better or equal. Generally, it is reinforced to increase its mechanical strength. Steel bands are used to line the sides of copper wheels used in seam welding, a special alloy of tungsten-copper is widely used on points for spot welding, dies for projection welding, etc., to a substantial saving over copper alone.

The high electrical conductivity of pure copper can and is frequently sacrificed by the engineer, provided he obtains a material with better strength and wear resistance. The metallurgist possesses a number of means of improving a given metal in strength and wear resistance by alloying. Unfortunately, we know just as well that in practically every case an enormous drop in conductivity ensues. However, in many cases, alloys give excellent results, even when the conductivity is far below the figure for copper. We will mention a few alloys that have proved very satisfactory.

Jaws in flash welding machines
Clamps in Butt welding
Dies and welding fixtures in continuous spot welding machines.

In selecting a suitable material for this type of fixtures aluminum bronzes have proved far superior to other metals, due to the great variation obtainable by minor changes in composition and treatment, giving a wide range of useful combinations of properties. They have higher electrical conductivity for the same hardness than other bronzes and brasses, also a higher heat conductivity and resistance to surface oxidation. Their resistance to wear is equal to or better than the best phosphor bronze.

Welding jaws for welding thin sections of sheet metal, such as used in automobile body manufacturing (flash welding) must be made of a metal that will withstand the pressure applied without deformation, as the contact surface must be in perfect alignment and even a very small variation causes arc affects and burns, which damages the work. The pressure may be as high as 30 tons per jaw or 1150 pounds per square inch. This is higher than the elastic limit in compression of copper at the existing high temperature, also copper is completely softened when held at a temperature of 350 deg. Fahr. for 72 hours. The alloys that have successfully been used are aluminum bronze with an iron content ranging from 2 to 4 per cent aluminum up to 12 per cent. The hardness may be as high as 50 (Sceleroscope), and the tensile strength from 65 to 85,000 pounds per square inch. The electric conductivity compared with copper is 12 per cent. The writer would suggest an alloy of only copper and aluminum having a slightly lower degree of hardness, but with higher electric conductivity lined with Elkonite especially on the lower jaws. The life of the jaws are materially increased and scraping operations, when necessary, are more easily performed.

Clamps for butt welding vary in design in different types of machines. They are generally of heavy copper, to allow for the passage of the large volume of current. Where heavy production prevails such as in butt welding of steel window frames in the automobile factory, aluminum bronze of extreme hardness has replaced copper, as the clamps are liable to get very hot on continuous runs of heavy work, and as heat affects the conductivity of the clamps they are often water cooled.

For dies and fixtures for continuous spot welding an aluminum bronze alloy containing no iron has proved quite satisfactory. A high conductivity is necessary as well as an absolutely homogeneous casting, as it is often cored and has thin wall sections for artificial cooling. These castings outlive copper 5 to 1 and up to 7000 welds per hour can be made in continuous production. The physical characteristics of this alloy is as follows:

T.S. 71,000 pounds per square inch
Brinell 137,
scleroscope 28,
Electric conductivity 23.7 per cent of copper.

This conductivity may seem abnormally high, but it appears correct, since test by three different observers produced the same result. The copper piece used for comparison showed a conductivity of 9.8 micro-ohms per cm. cube.

Electrodes for Seam Welding.—Owing to the high density of current

and the design of these wheels, a metal of high electric conductivity must be used. The wear on these wheels is rapid due to the pressure and heat. Copper predominates since alloys fail to come up to the high conductivity figure necessary. Rolled copper is mostly used since its hardness is greater. Often a dressing tool mounted on the machine for dressing the wheel when it becomes jagged eliminates the dismantling and saves time. For this purpose, the writer has tried aluminum bronze of various compositions, but with little success. Best suitable seemed to be an alloy developed by Corson containing 1.8 per cent Cobalt, and 0.5 per cent silicon quenched from 870 degrees before being hardened at 350 to 550. However, sufficient comparative tests to prove its value have not been made as yet, but it may point the way to finding an alloy for this type of electrode. This allow showed 66 per cent electric conductivity of copper and 160 brinell hardness.

Points for spot welding.—For welding of high resistance metals, copper has not yet to date been substituted. However, to eliminate its tendency to mushroom and become flattened out, it is lined at the point of contact with heat resisting alloys greatly increasing its life. Elkonite, as mentioned before, is extensively used to a great saving. The use of chromium metal in this connection is very interesting. The physical characteristics point to its usefulness for this purpose, its high electric conductivity coupled with its high resistance to oxidation and mechanical wear. The electric conductivity is 63 per cent of copper. Brinell hardness 200 (1000 Kgm. load), Rockwell hardness 100 (1/16 point at 100 Kgm. load), T.S. 100,000 pounds per square inch. Points chromium plated to a thickness of 0.005 for welding non-ferrous metals (aluminum and brass sheets) had twice the life of copper alone.

For manufacturers and those who build their own welding machines, it is worth while to thoroughly investigate aluminum bronzes, especially for large castings where strength and non-magnetic properties are sought rather than conductivity. The best composition of aluminum bronze is probably the alloy containing only copper aluminum. Large intricate castings of this composition have been made and have proved vastly superior to other compositions containing iron, titanium, silicon, etc. Electric conductivity tests also proved it carried 9 per cent more current with same drop of potential and temperature rise. If the alloy is cast homogeneous, water for cooling can be carried through holes drilled in castings which allow the water to come in the direct contact with same, thus cooled in a simple manner. If the castings are not homogeneous steel pipes have to be cast in order to overcome porosity troubles. This lowers the cooling effect of water tremendously owing to steel being a poor contact between O. D. of pipe and casting, also steel pipe frequently defeat their objective by generating heat, due to their becoming an iron core in a closed electric circuit.

As mentioned before, aluminum bronzes are very sensitive to treatment and it is quite important that the foundry man knows not only how to produce metal free from blowholes and surface defects, but also how to obtain the desired mechanical and physical qualities.

Large Gas Line Is Arc Welded

A. F. DAVIS†

GAS will soon flow through the Uinta Pipe Line Company's new arc welded line from the junction of gathering lines, which is southeast of Rock Springs, Wyo., to Ogden and Salt Lake City, Utah. The total length of the line, when completed, will be 277 miles. Of the total mileage, 200 miles is of 18-inch pipe, the balance being of 16-inch pipe consisting of a 42-mile branch to Ogden and a 35-mile branch to Salt Lake City.

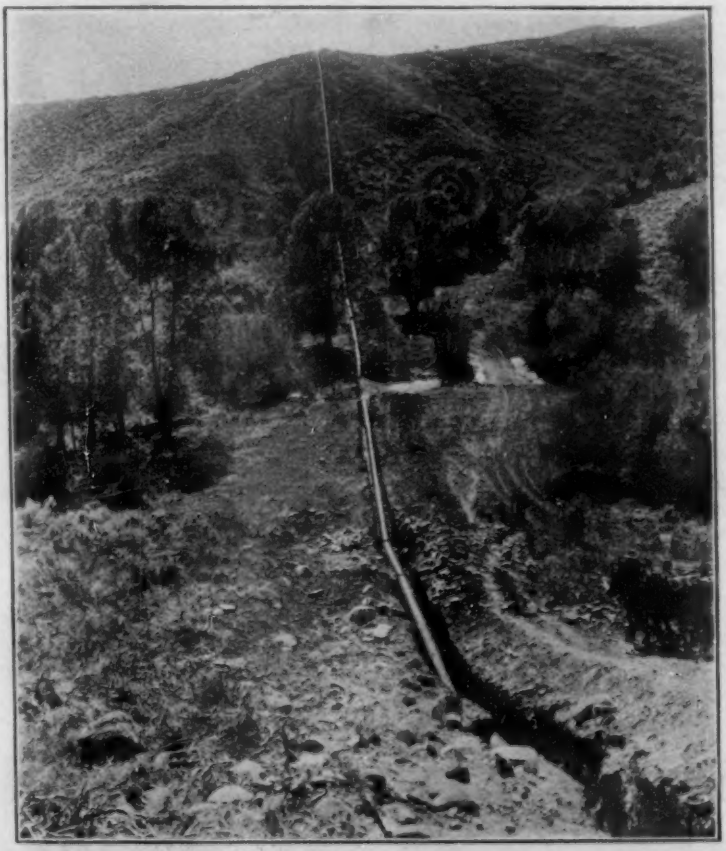

FIG. 1—A GRADE OF 60 PER CENT DOES NOT STOP PIPE LINE CONSTRUCTION. SECTIONS THAT COMPRISE THIS PORTION OF THE LINE WERE ARC WELDED ON TOP OF THE HILL AND THEN LOWERED INTO POSITION

†Vice-President, The Lincoln Electric Co., Cleveland, Ohio.

The pipe used in this gas carrier is of arc welded manufacture produced in 30-foot lengths having bell, and spigot with welding dam ends. Each length weighs 1600 pounds. Due to the ruggedness of the country and the steep grades encountered, some of the pipe had to be snaked into position by tractor, after having been delivered as near location as possible by truck. Some idea of the nature of the country traversed by this line

FIG. 2—MAKING A FIRING LINE WELD ON A RAINY DAY. A TARPAULIN FORMS THE WINDBREAK. NOTE ROLLERS UNDER PIPE TO FACILITATE TURNING THE SECTION DURING WELDING

FIG. 3—A TYPICAL BELL AND SPIGOT JOINT WITH WELDING DAM. THE TACK WELDS HOLD PIPE IN LINE, UNTIL THE POINT IS COMPLETELY ARC WELDED

may be obtained by observation of figure 1, which shows a completed portion of the line on a 60 per cent grade.

The customary practice of lining up a number of lengths of pipe to form a section is followed in the construction of this line. The number of pipe lengths in each section varies, depending upon the contour of the ground. In lining up a section, the spigot ends of the pipe lengths are

FIG. 4—A TYPICAL FIRING LINE SCENE. THE WELDING OPERATIONS ARE HIDDEN FROM VIEW BY THE WINDBREAKS

FIG. 5—READY TO ARC WELD THE FINISH BEAD IN A BELL HOLE JOINT

inserted into the bell ends and the entire section, thus formed, is leveled by shoring or blocking up with timbers. One innovation which facilitates turning of sections, during welding operations, was introduced on this line. A set of four steel rollers consisting of two pair mounted on a steel channel base is placed on the top shoring timber on which the pipe rests. A view of a set of rollers is shown in the foreground of Figure 2.

After the pipe is lined up and leveled in sections, each joint is tack welded, as shown in Figure 3. This is necessary to keep the section intact, due to extreme changes in temperature which, through contraction

FIG. 6—TYPE OF EXPANSION JOINT USED, ALSO ILLUSTRATING COMPLETED ARC WELDED JOINTS

and expansion of the pipe, causes it to open the joints or buckle, as the case may be. By tack welding, the pipe lengths are joined so that contraction and expansion acts on the section as one unit instead of as separate pipe lengths.

Each joint in the section is arc welded twice, two separate beads being run around each joint. This is done to prevent all possibility of pin hole leaks. The first, or burning-in bead, is arc welded with 3/16 inch electrodes. Approximately ¾ pounds of electrode metal is used to weld the burning-in bead in the 18-inch joints on this line. The second, or finish, bead is arc welded with ¼ inch electrodes, approximately 1¾ pounds being consumed in making the finish weld. On the firing line which is the scene of welding the pipe lengths into sections, welding speeds ranging from 8 to 12 joints per man per day are being obtained. Typical firing line scenes are shown in Figure 2 and Figure 4.

After the pipe is welded into a section, the section is then placed over

the open trench on skids and welded into the line. This welding is known as bell hole welding. Being unable to turn the line, the operator must weld around the pipe, necessitating overhead welding. Only in this respect does bell hole welding differ from firing line welding. The speed of welding bell hole joints of this line varies from six to eight joints per operator per day. Figure 5 shows an operator ready to weld the finish bead in a bell hole joint.

To take care of the expansion and contraction of the finished line, caused by temperature changes, a special type of an expansion joint of all steel construction is welded into the line at intervals. Figure 6 shows a typical expansion joint, also examples of completed arc welded joints.

The major portion of this line is being arc welded by the owners, the Uinta Pipe Line Company, who are using ten welders which are of the gas engine driven type of 300 ampere capacity with a current range of 75 to 400 amperes, and operating at a speed of 1500 r.p.m. The engine is of the six cylinder type which is so essential for machines at this speed to eliminate all vibration. It is directly connected to the generator by a flexible coupling and both mounted on a structural steel channel base. The welders are mounted on wagons and are moved along the line by teams.

This pipe line is the first of 18-inch size to be arc welded. The unusual success experienced with the use of arc welding by the owners in the construction of this line augurs well for the extensive use of electric arc welded construction on all future gas lines. While at this time, definite figures of the cost of welding joints are not obtainable, the owners estimate the cost of the arc welded joints to be less than those made by other methods. Additional advantages offered by use of the electric arc process are greater welding speed and stronger, more durable joints.

Present Status of Welding in the A.S.M.E. Boiler Code*

C. W. OBERT†

THE Boiler Code Committee of the A. S. M. E. is, in view of its advisory relationship to not only the inspectors' organization but also the boiler and pressure vessel industry at large, expected to codify rules that will provide for any form of pressure vessel construction. This has indeed been the committee's aim, but the committee has been accused of neglect of duty and obstructionism because it has not succeeded in developing a set of rules that would be broadly applicable to welded tank and drum construction. It is true that when the Boiler Code was first written the rules therein were limited to customary forms of riveted and forge-welded construction, and that no reference was made therein to fusion welding as applied to either boilers or pressure vessels, but the art of welding had not at that time (1914) developed to the stage where sufficient authentic data on the strength of welded joints was available.

During the years that followed the issuance of the Boiler Code numerous requests have come to the committee to investigate and provide for recognition of the new art of joining metals, and since 1916 the subject has been before the committtee in one form or another almost continually. The committee has from time to time made earnest endeavors to obtain the necessary data that would permit of formulating suitable rules for fusion welded joints, but the records of several public hearings that were held on proposed rules are eloquent testimony to the unpreparedness of the welding industry prior to 1923, when the first edition of the A. S. M. E. Unfired Pressure Vessel Code was issued. The committee attempted to cooperate with individuals, organizations and governmental bureaus in the endeavor to solve this difficult problem, but until recently it has received little real assistance.

The Unfired Pressure Vessel Code embodied the first tangible results of these studies of the welding art, but the limits imposed therein on the application of welding were such as to narrow the use of welded construction principally to air pressure tanks of comparatively small sizes. There was much discussion as to whether the rules should require the tanks to be strain annealed after welding and it was decided to issue the rules without including any requirements for strain annealing. Naturally, the allowable working stresses for tanks that are not strain annealed are lower than for tanks in which the strains have been removed through annealing. This was naturally disappointing to those interested in the advancement of the welding art, but in the absence of the much-

*Presented at meeting of Philadelphia Section of American Welding Society, October, 1929.

†Union Carbide and Carbon Research Laboratories, Inc., Long Island City, N. Y.

looked-for method or means of testing or measuring the strength of the welded joint, the limits of 20 in. in diameter, length not to exceed three times the diameter, working pressure of 100 lb. per sq. in., plate thickness of $\frac{5}{8}$ in., and unit working stress of 5600 lb., represented the best that could be agreed upon by the Boiler Code Committee and that would prove acceptable to the inspectors' organization at that time. This section of the code was accordingly issued with the very distinct understanding that as the art developed and sufficient information became available, the committee would be glad to revise and amplify the rules in question.

It was shortly after this accomplishment that effective cooperation was inaugurated between the Boiler Code Committee and the American Welding Society, which marked the beginning of the real development of this phase of the committee's work. A special committee of the Welding Society has contributed valuable data and information to the Code Committee, and continues in its close relationship to furnish such assistance as it can for both the interpretation and revision work. No welding problem is now considered without referring it to the cooperating body, and effective and satisfactory results are now being obtained. I think it is now fair to state that the interests of the Code Committee and the Welding Society are practically identical.

While only a few States and cities have accepted the A. S. M. E. Unfired Pressure Vessel Code, the State of California took action in 1926 toward adopting the essentials thereof, except that the limits on welded construction were broadened considerably over those in the A. S. M. E. code; for instance, the diameter limit was increased to 60 in.; the pressure limit to 200 lb.; and the unit working stress in double V longitudinal joints to 8000 lb. per sq. in. In common with the A. S. M. E. Unfired Pressure Vessel Code there were no requirements for strain annealing the tanks after welding. The California Department of Safety was solicitous of the sanction which the Boiler Code Committee might give to such changes in its Pressure Vessel Code and requested its opinion thereon, with the result that the committee approved of such modifications of the code, provided the State could enforce such regulations and restrictions as would insure sound and safe welding. This the California Department was able to establish by a form of registration for manufacturers, and their code went into effect on January 1, 1928. So far as the writer has been able to learn, the results have been generally satisfactory.

In connection with the efforts of the American Welding Society to liberalize the established rules for welded construction, a step of great importance was taken when it formulated a Recommended Procedure for sound and safe welding, which was formally presented to the Boiler Code Committee last February. This Recommended Procedure established for the first time in the history of this work a code of rules for welded construction which, if followed out, could be expected to provide safe welded vessels. The Boiler Code Committee after making a study of this procedure, decided that it promises to furnish that connecting link between fusion welding and sound, safe construction, which is so greatly needed, and immediately took steps to so revise the Unfired Pressure Vessel Code as to render it uniform with the modifications in the California Code. These revisions are now in process, awaiting publication

before being officially approved and issued. A slight delay has been incurred as a result of criticism of certain details of the new procedure, but this is being ironed out by the Conferring Committee of the American Welding Society and is expected to be soon adjusted. It is the expectation that this revision will be completed before the end of the year.

If the details of the above-mentioned revisions of the A. S. M. E. Unfired Pressure Vessel Code are of interest, it can be said that they are now nearly completed and are expected to be ready for publication in the near future. These revisions will extend the diameter limit for tanks in which no strain annealing is required after welding from 20 in. to 60 in., the pressure limit from 100 lb. per sq. in. to 200 lb. per sq. in., and the allowable unit working stress for double V longitudinal welds from 5600 lb. per sq. in. to 8000 lb. per sq. in. Supplementary provisions are also made for allowable unit working stress of 6500 lb. per sq. in. for butt, single V girth or head welds; 7000 lb. per sq. in. for double, full fillet lap or girth welds; and 5600 lb. per sq. in. for spot or intermittent girth or head welds. These extended limits are applicable, however, only in case that the Recommended Procedure, which is to be issued together with these revisions, is followed in detail, and the vessels are fully inspected during construction and at the time of hydrostatic test. It is provided in the code that if the requirements of this procedure are not followed, the limitations that formerly existed will continue to apply. The net result of this new departure is that only a well-equipped fabricating shop with qualified welders and considerable experience concerning pressure vessel construction will be in a position to take advantage of these new rules. This advance step taken by the Boiler Code Committee appears to be well thought out and wholly justified from every point of view.

The use of autogenous or fusion welding is sanctioned in Section IV of the A. S. M. E. Boiler Construction Code which bears on the construction of heating boilers. Steel plate boilers constructed under the prescribed rules for fusion welding may be used for steam heating at pressures not to exceed 15 lb. per sq. in., and for hot water heating at pressures not to exceed 160 lb. per sq. in. At a more recent date the use of the Thomson electric method of welding was sanctioned for power boilers as the equivalent of forge welding.

The Boiler Code Committee has proposed specifications for fusion welding of drums of power boilers for embodiment in the Power Boiler section of the code. These specifications include requirements which are more exacting than those in the Unfired Pressure Vessel Code, such as for strain annealing after welding, for impact tests, for physical tests to be made on the welds, chemical analyses, macro and micro tests of the welded metal and non-destructive tests of the completed vessel. These specifications have been referred to the Conference Committee of the American Welding Society and to the Sub-Committee of the Boiler Code Committee on Welding for approval. The Boiler Code Committee hopes that these, or similar specifications, will be agreed upon for inclusion in the code. It is the intent of the Boiler Code Committee to bring the matter to a final conclusion as speedily as possible.

In view of this activity in connection with the rules for welding, the State of Ohio has recently taken action to adopt the A. S. M. E. Unfired Pressure Vessel Code, together with the modifications embodied in the revisions now under consideration; their new rules will go into effect in Ohio on January 1, 1930. Similar action to modify the rules in accordance with the revisions under consideration, is now being taken by the State of Oregon, which was one of the first communities to enforce the rules of the Unfired Pressure Vessel Code. Similar moves are being talked of in the cities of Seattle, Wash., and Detroit, Mich., but the writer has not learned of definite results as yet. The States of New York and Pennsylvania have given some study to the question of pressure vessel rules, and may perhaps take action thereon in another year or so if the revisions in the welding rules go through and work out satisfactorily. The chief boiler inspector of New Jersey also favors the revisions, and is preparing to act along similar lines.

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